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STUDIES FROM THE LABORATORY FOR SURGICAL RESEARCH.

DEPARTMENT OF SURGERY.

COLUMBIA UNIVERSITY.

VOL. I.—1903–1907.

INTRODUCTION.

This collection of reprints comprises the majority of the published reports of the studies and investigations carried on in the Laboratory since its inception in 1903. At first only a small room was available for the use of the Laboratory and little could be accomplished. For the past two years it has occupied three small rooms, formerly used as bedrooms for students attending the Sloane Maternity Hospital, and besides the research work, a course in surgical technique has been given to the students of the third year class of the Medical School.

By far the greater part of the reprints represent work done in these two years, and over half, that done in the past year. At present the demand for time and space far exceeds the capacity of the Laboratory and would-be investigators have to be turned away and the work on important problems deferred. The situation calls for enlargement of the Laboratory and endowment

Some of the enclosed publications, although dealing with the same subject, have appeared in different journals. For this reason, and in order to collect all the publications of the Laboratory together for the use of those interested in it and its work, it has seemed best to issue a limited number of copies of this volume.

Joseph A. Blake, M.D.

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* Number of reprints limited.

REPRINTED FROM
ANNALS OF SURGERY
OCTOBER, 1907.

STUDIES IN INTESTINAL EXCLUSION.*

BY JOSEPH A. BLAKE, M.D.,
AND
R. M. BROWN, M.D.,
OF NEW YORK.
From the Laboratory for Surgical Research, Columbia University.

THESE studies were prompted by an operation upon a patient of one of the writers in whom, in order to reëstablish the continuity of the large intestine after the resection of the sigmoid flexure, an unusual anastomosis was employed.

The patient, a man fifty-six years of age, was operated on June 11th, 1906, for intestinal obstruction caused by what was supposed to be carcinoma of the sigmoid flexure but was afterwards proven to be hyperplastic tuberculosis. At operation the entire sigmoid flexure was found to be implicated in a mass which also invaded the bladder and the left spermatic cord. In order to remove it, it was necessary to sacrifice a portion of the descending and the upper part of the pelvic colon. The hiatus was so great that the ends could not be brought together without exerting undue tension, consequently the upper end of the remaining portion of the pelvic colon was implanted into the side of the middle of the transverse colon. This resulted in the formation of a blind pouch or cecum distal to the anastomosis (Fig. 1). The arrangement may be termed a unilateral aboral exclusion. It was recognized at the time to be faulty but the patient's condition precluded further interference and there was no certainty that it would provoke serious trouble.

The immediate convalescence from the operation was perfectly smooth and the patient gained twenty-eight pounds in the following two months. During this time he complained at times of colicky pains and there seemed to be accumulations of gas

* This and the eight accompanying papers by Drs. Eggers, Greene, Leggett, Maury, Blake, and Beer represent the results of studies conducted during the session 1906–07, in the Laboratory for Surgical Research, College of Physicians and Surgeons, Columbia University.

and fecal matter in the excluded loop. This could be relieved by irrigations with a long rectal tube. Excision and division of the loop were considered but were not advised on account of the

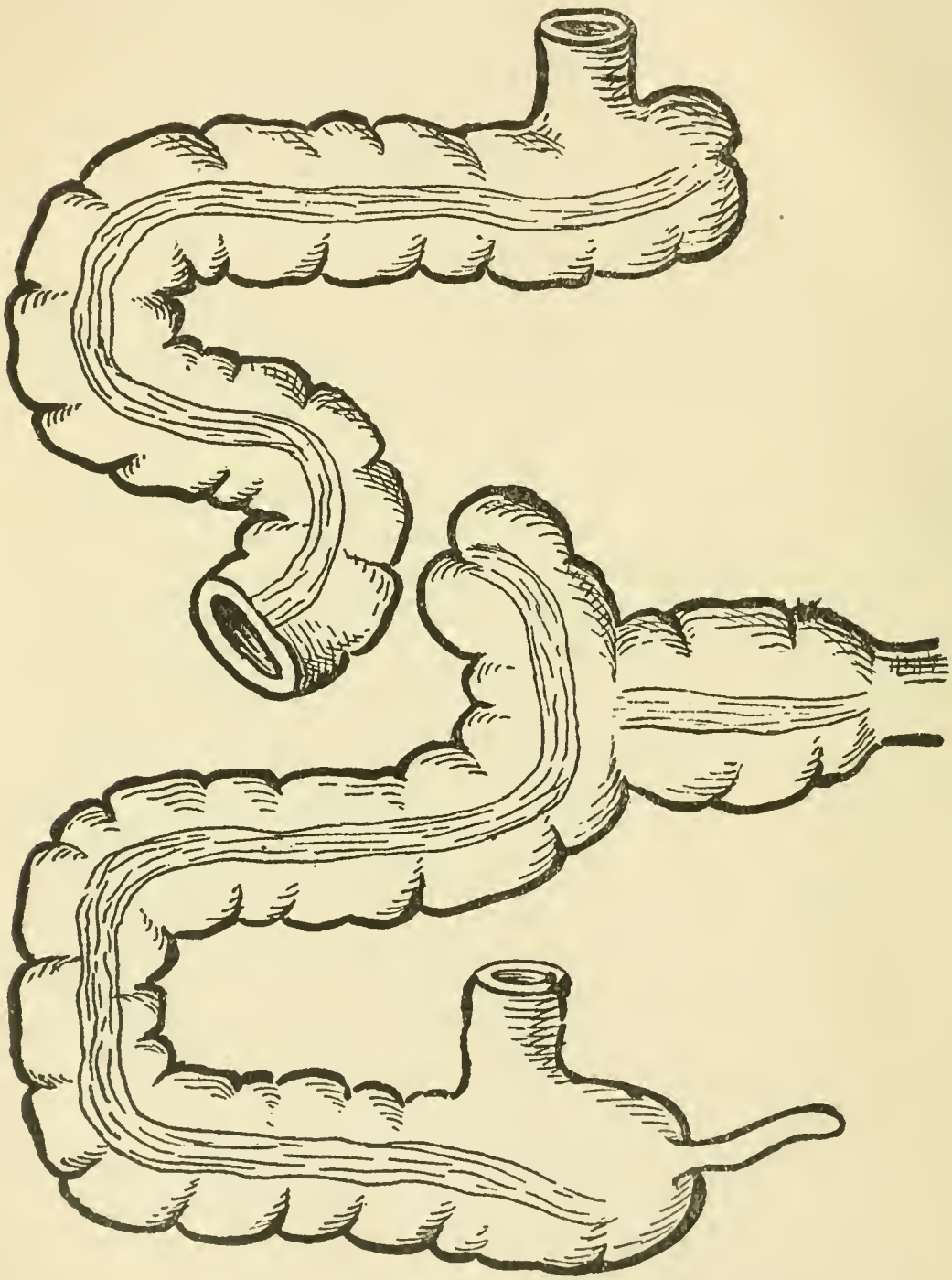


FIG. 2.—Showing arrangement after division of aboral segment and closure of proximal end. The totally excluded loop now communicates with the exterior at both ends; the distal opening being the one formed by spontaneous rupture.

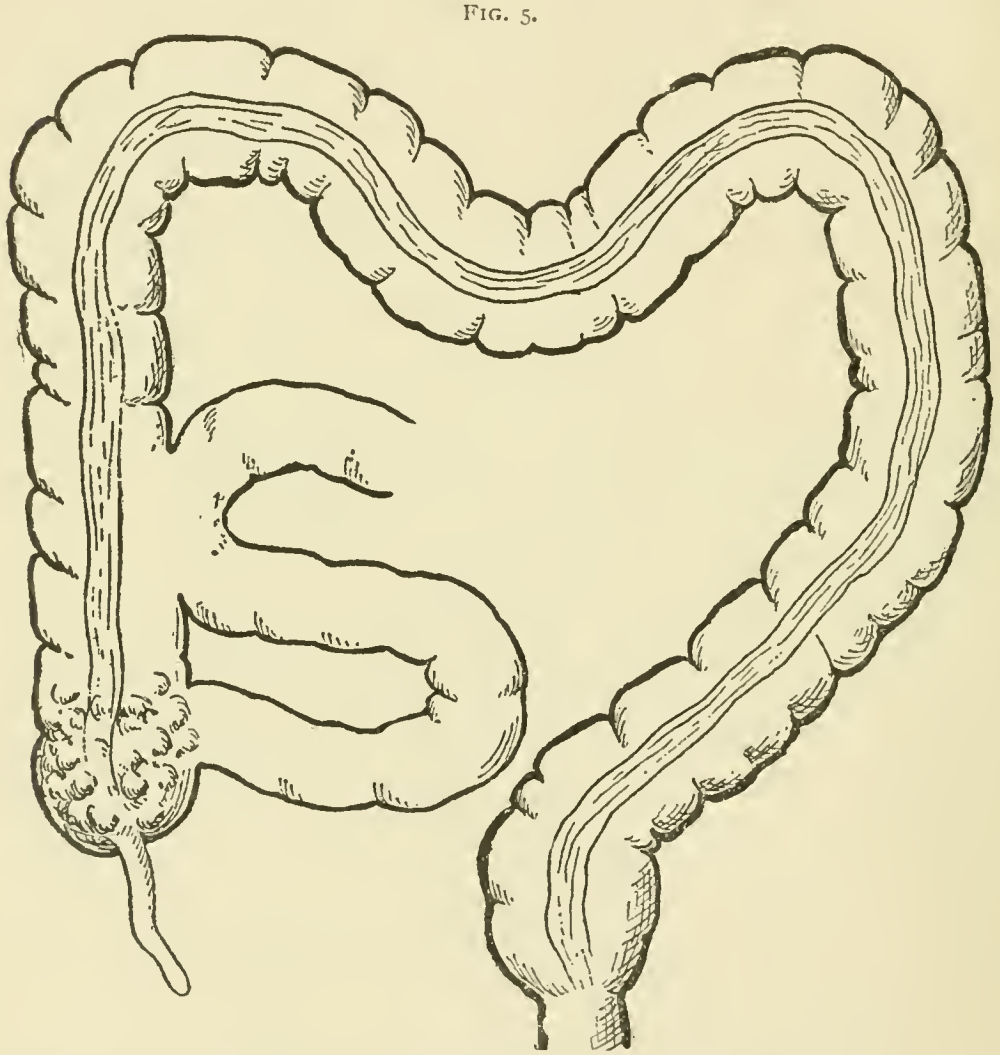
continued improvement of the patient. In the meantime, he went to his home in a neighboring city and resumed his business.

During the winter the trouble from accumulation in the blind end increased necessitating daily irrigations and finally, at the end of January, 1907, perforation at the blind end occurred with the formation of an abscess. This was opened at Atlantic City. After remaining there for some weeks, he was brought to New York with a narrow sinus discharging pus, gas and fecal matter. The discharge occurred more or less intermittently and at times would be accompanied by sharp colicky pain due to the peristaltic efforts of the loop to empty itself. The patient's general condition was bad, he had lost much weight and was running a low grade septic fever. By increasing the drainage his condition was improved and on April 15, 1907, ten months after the first operation, the transverse colon was divided just distal to the anastomosis with the pelvic colon, the proximal end was closed and the distal end brought up into the incision (Fig. 2). The operation was exceedingly difficult on account of the adhesions. The loop now is a bilateral exclusion with a proximal opening; the distal end communicating with the skin by the fistulous tract. Water injected into the proximal end, escapes at once from the fistula but when injected into the fistula it does not escape from the proximal end, showing that it does not readily pass against peristalsis. Four months after the operation, the sinus communicating with the proximal end of the excluded loop barely admits a No. 12 French catheter and there is no discharge from it. The distal end is also open and communicates with a fistulous tract leading to the point where the intestine was closed just beyond the anastomosis. The discharge being mingled with a small amount of feces escaping from the latter its character and amount cannot be determined. However, as far as can be ascertained, the excluded loop has contracted so that it will hold only about an ounce of fluid.

The necessity for anastomosing the pelvic into the transverse colon seldom occurs. An extended search of the rather voluminous literature of intestinal anastomosis and exclusion failed to reveal a similar instance. As a rule, obstructing growths of the sigmoid flexure do not involve an extent so great as not to permit of end to end union after resection. Not having data derived from former cases and anticipating

trouble from accumulation in the distal blind segment, similar operations were performed on dogs, the large intestine being divided just above the rectum, the oral end completely closed and the aboral end united end to side to the large intestine just distal to the ileocecal junction. The first dog was operated on November 19, 1906, and no adverse symptoms,

FIG. 5.



Lateral anastomosis between the ileum and ascending colon, for the purpose of shunting the intestinal contents by an obstruction in the cecum.

excepting a temporary diarrhœa, being noted, the operation was repeated on another on February 7, 1907. This dog also suffered from diarrhœa for several weeks after the operation. On April 27, 1907, both dogs were killed.

Examination of the blind intestine beyond the anastomosis showed that the intestinal contents had been crowded toward

the closed end dilating it to more than twice its normal diameter. Just beyond the anastomosis the diameter was practically normal which increased from there on to its maximum at the blind extremity (Figs. 3 and 4). After a greater

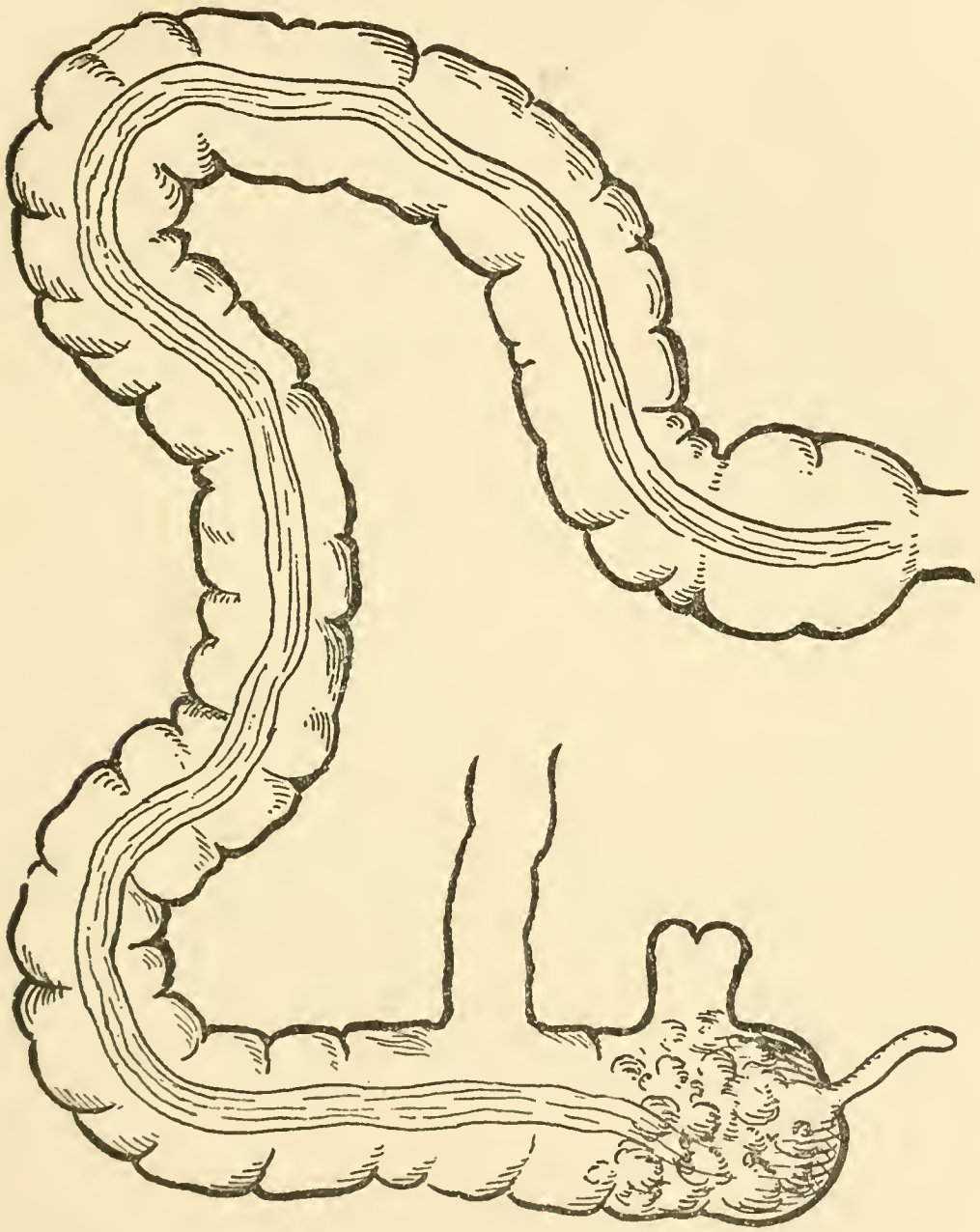
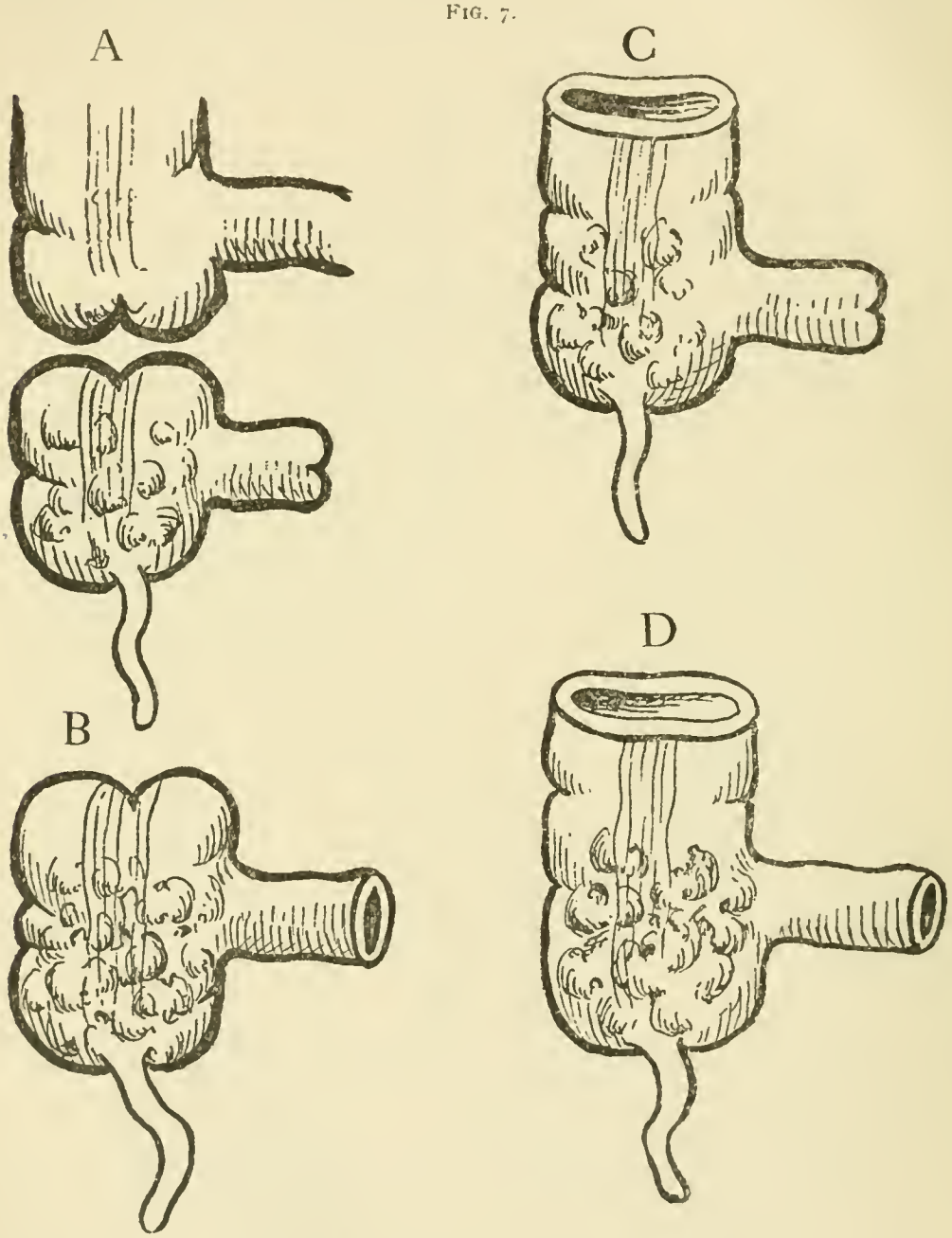


FIG. 6.—End to side implantation of ileum into ascending colon with occlusion of distal end of ileum. The segment comprising the distal portion of the ileum and the cecum is unilaterally or incompletely excluded and is unilaterally occluded.

lapse of time it is probable that perforation would have occurred in the dogs as it did in the man, either from ulceration or penetration by some foreign body accidentally ingested.

The results of the operation upon the patient and the dogs show that aboral partial exclusion of the intestine is a faulty and dangerous procedure. If the excluded segment cannot be

FIG. 7.



Bilateral or complete exclusion, with A, total occlusion B, dista. occlusion C, proxima occlusion and D, both ends open and attached to skin.

excised, it should at least be totally excluded as was accomplished by the second operation in the case reported.

The objectionable features of such operations also apply to the ordinary lateral anastomosis performed to shunt the

intestinal contents by a diseased segment of gut. In such cases, if the obstruction is complete, accumulation occurs in that portion of the excluded loop which is proximal to the obstruction (Fig. 5). This objection has been recognized for a long time although its dangers have not been fully appreciated. In cases of fistula or when, for any reason, the presence of feces in the excluded loop is objectionable, lateral anastomosis is a complete failure inasmuch as the feces are not prevented from passing into it. For these reasons the end to side anastomosis resulting in a unilateral exclusion as recommended by Senn, is preferable (Fig. 6). Even when this operation is performed, fecal matter gathers to a certain extent, in the excluded segment on account of the double direction of the peristaltic movements in the large intestine, and if this is undesirable, complete exclusion as recommended by Salzer, should be performed; at least one end, preferably the distal, of the excluded loop being united to the skin (Fig. 7).

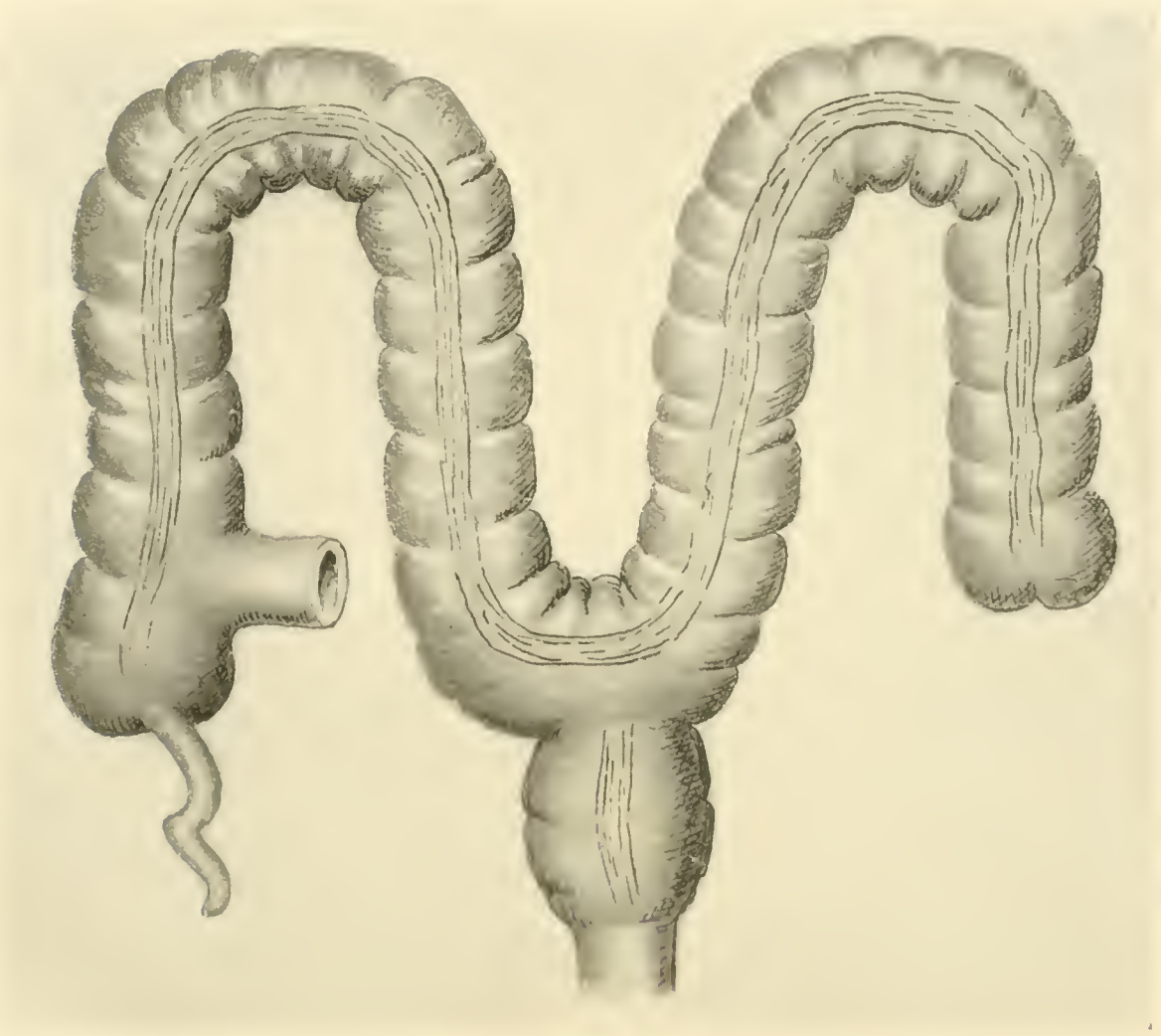
Unless one or both ends of a completely excluded loop communicate with the skin, or a communication exists by means of a fistula, troublesome accumulation is apt to occur. According to Reichel (Centralblatt f. Chirurgie, Bd. 22, S. 37) in experiments on animals, accumulation may or may not occur. Obalinski states (Centralblatt f. Chirurgie, Bd. 22, S. 129) that complete exclusion with total occlusion of the large intestine is safe but of the small intestine is dangerous on account of the preponderance of the secretory over the absorptive functions of the latter. According to Wiessinger (Deutsche Zeitschrift f. Chirurgie, Br. 62, S. 1) only one of four cases of complete exclusion with total occlusion was successful up to 1901, either rupture occurring with fistulous formation or death.

In order to determine the safety of complete exclusion combined with total occlusion of the large intestine, a series of five experiments were made on dogs. Two of the animals died of peritonitis immediately following the operation and the identity of one was lost leaving only two in which the result could be observed. One of these was killed four weeks

after the operation and the excluded segment was found to be distended with what was apparently fecal matter, to three times its normal diameter (Fig. 8). On section the walls were hypertrophic rather than thinned. The other animal was killed three weeks after operation and the result is well shown in Fig. 9. The photograph was taken one-half hour after the removal of the specimen and shows peristaltic contractions still taking place in the excluded segment. It is also interesting to note that the distal end is more distended than the proximal as a result of the peristalsis. The result of these experiments indicates that total occlusion, even of the large intestine is dangerous on account of distension of the segment by the excretions of the intestine. They also indicate that distal occlusion has the same effect upon the excluded loop as any obstruction has upon the intestine in general, namely, in increasing peristalsis and causing hypertrophy of the muscularis.

During the coming Winter further investigations will be carried out to ascertain the morphological and chemical nature of the semi-solid matter found in the excluded intestine. Its rapid accumulation is confirmatory of the theory that at least a large portion of the feces is excreted by the intestinal mucosa and that the function of the large intestine is not entirely absorptive.

FIG. 1.



Implantation of oral end of remaining portion of pelvic colon into side of transverse colon. The portion of the colon distal to the anastomosis is aborally excluded.

FIG. 3.

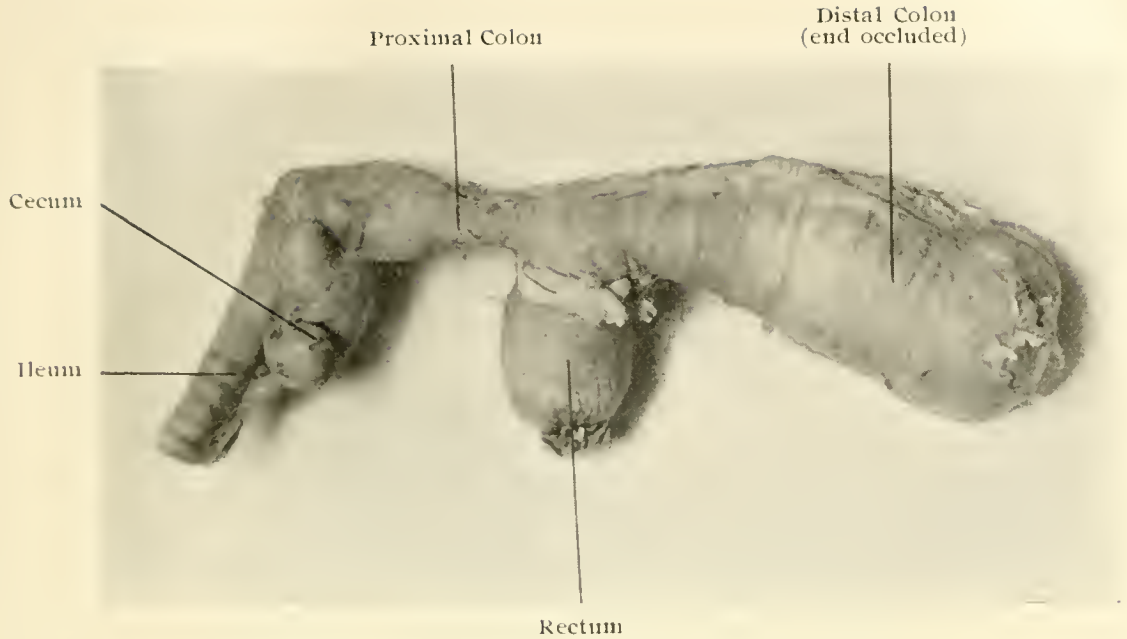

Proximal Colon
Distal Colon
(end occluded)
Cecum
Ileum
Rectum

FIG. 4.

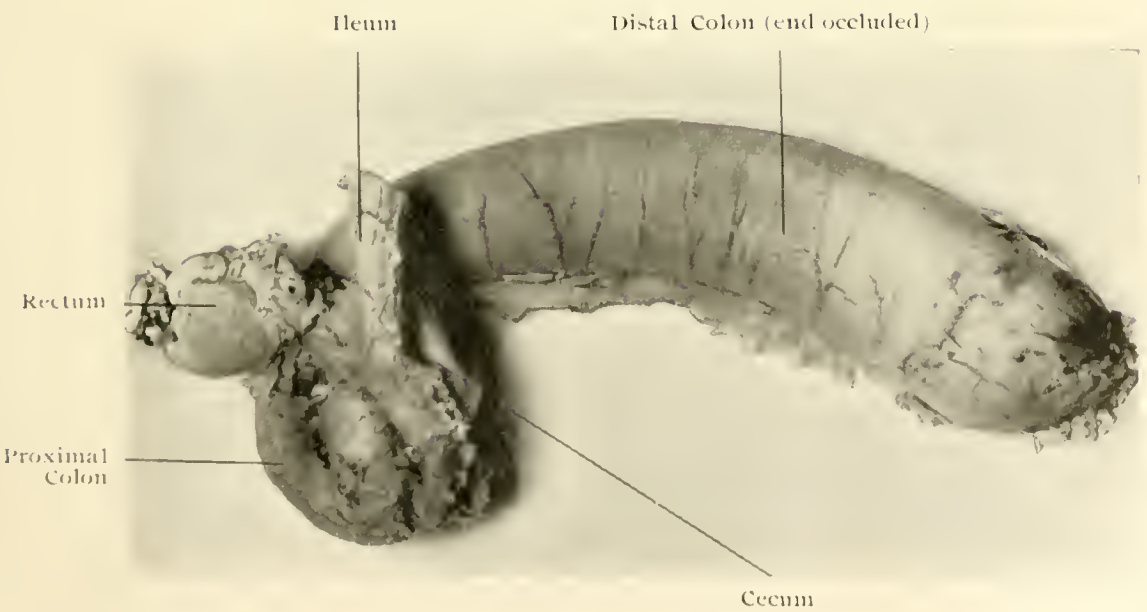

Ileum
Distal Colon (end occluded)
Rectum
Proximal
Colon
Cecum

FIG. 8.

Photograph ⅔ natural size of completely excluded and occluded large intestine.

FIG. 9.

ARE THE INTESTINES ABLE TO PROPEL THEIR CONTENTS IN AN ANTI-PERISTALTIC DIRECTION?*

BY EDWIN BEER, M.D.,

AND

CARL EGGERS, M.D.,

OF NEW YORK.

In the following pages we wish to bring together some of the evidence in favor of an affirmative answer to the above query. The evidence in favor of such an anti-peristaltic movement is both clinical and experimental. How frequently under normal conditions such movements do occur in the human intestine remains to be determined by future investigation. Here we are concerned only with the question, can the intestines propel their contents in an anti-peristaltic direction?

That this question is not altogether simple is evident. That it is not settled will be readily gathered from the statements to be quoted from recent authoritative writers. In Wilms' book on Ileus just published (on p. 26) he states, "An anti-peristalsis, that is, an evident upward peristalsis driving the contents of the bowel towards the pylorus, and not towards the anus, does not occur." On the other hand, W. J. Mayo, American Journal of the Medical Sciences, January, 1907 (p. 4), states, "The normal action of the upper colon is anti-peristaltic except during defecation," and further, "Murphy has shown that salines introduced very slowly into the rectum will be absorbed with great rapidity, largely by reverse peristalsis to the cecum." These opposed views, recently expressed, show the need of further study along these lines, and we trust that the following array of evidence will convince

* From the Surgical Research Laboratory, College of Physicians and Surgeons, Columbia University. Presented in part at the New York Academy of Medicine, May, 1907.

many who at present agree with Wilms' in his statement of the case.

Before discussing the evidence gleaned from experiments in the laboratory, and from observations in the clinic, we must briefly analyze a phenomenon which in all probability does not concern this study. If some non-absorbable powder, such as carmine, be placed within the rectum of a patient with a colostomy opening, and smears be made from this artificial anus, one will almost regularly find, in a shorter or a longer time, granules of this powder. In other words, this carmine has wandered from the rectum up the bowel and out through the colostomy wound. This curious phenomenon can be observed by any one in such clinical material as above referred to, or in laboratory animals if desired. At first blush it looks like an affirmative reply to the question before us, for the contents of the rectum have wandered upwards in an anti-peristaltic direction. Perhaps in due time this phenomenon may be adequately explained. At present almost all investigators are inclined to interpret this upward wandering of carmine from the rectum to the colon, or even to the stomach or higher, as due to upward currents along the intestinal wall, quite independent of peristalsis. The fact that this phenomenon occurs despite stenoses of the bowel, the carmine wandering through these rigid parts, and the fact that intestinal quiet favors the ascent of the carmine seem to exclude this from the group of phenomena which point to the possibility of anti-peristaltic activity in the intestine. The final verdict, however, has not been reached as yet.

Of direct bearing on the question before us, are two groups of observations—the one gathered in the laboratory and the other in the clinic. Both are of great importance, and both must be analyzed carefully. The experimental work is the more important as the observations are fuller and perhaps more accurate, and these we shall take up first, leaving clinical evidence for later consideration.

There are two experimental methods of approaching the problem as to whether the intestine is capable of propelling its

contents in the reversed or anastaltic direction, and in our work, which has been in progress almost 1½ years, we have employed only one of these, and that which seemed to promise most to us. Instead of employing the method of direct observation of the unoperated bowel, with or without the use of the X-rays we have used the operative or functional method of testing the capacity of the intestine for working in the reversed direction, by resecting segments in the small and large bowel, turning them around, and sewing them in place in reverse position. If the bowel is capable of propelling food in the reverse direction, then this reversed piece of intestine will function isoperistaltically; in other words its normal downward peristalsis will give way from time to time, or altogether to what would, under normal conditions, be anti-peristalsis. Thus we would acquire rather conclusive proof that the intestine is capable of doing anti-peristaltic work, of accomplishing what Wilms so recently denied.

This method of approaching our problem is by no means original, as in 1889, Kirstein attacked the question of anti-peristalsis in just this way. Since his publication many others have repeated his experiments (Mall, Edmunds and Balance, Muehsam, Kelling, Kauders, Enderlen and Hess, Prutz and Ellinger), but the lack of uniformity in results has occasioned considerable confusion.

Wilms' recent statement that, "in the experiments of Prutz and Ellinger, who have again carefully analyzed the anti-peristaltic intestinal movements, it is conclusively proven that the reversed segment shows the same peristalsis as before reversal, and that no real anti-peristalsis develops," fails to throw any light on this subject; in fact in our opinion, adds to the difficulties already existing. A brief review of the published work, and a careful analysis of Prutz and Ellinger's experiments will show, we believe, how erroneous Wilms' conclusion is.

In our opinion, the most satisfactory method of arriving at well-founded conclusions in these reversal experiments is by the direct study of the behavior of the reversed loops. That

is the only sure way of deciding in which direction the peristaltic waves progress. A second, but less accurate and decidedly inferential method of arriving at valid conclusions, is that in which reversals of extensive segments of the bowel are made. In such animals, regular defecations must be the sign of downward or katastaltic waves, as one cannot conceive of the intestinal contents traversing very large segments of reversed bowel towards the anus, unless the peristaltic waves propel them in that direction.

With these two methods and view points in mind, let us briefly review the work done along these lines, and then take up our own experiments which were done in part by ourselves, and in part by the students of the College of Physicians and Surgeons under the careful supervision of Dr. Maury.

A. Kirstein [1]—1889—operated on two dogs, reversing segments of the small intestine. He attempted a direct study of the peristalsis in one of his animals, but his attempt was unsuccessful. He noted at autopsy, the animals being killed 7 weeks and 3 months, respectively, after the operation, that at the upper anastomosis there was a spindle shaped dilatation with hypertrophy extending above and below the upper end to end anastomosis, and bisected by this. This dilatation he explained as the result of the two peristaltic waves working against each other. He concluded, with perfect propriety, that the peristalsis in the reversed gut must be reversed at least from time to time, to allow of the downward passage of intestinal contents through a reversed segment, which was ¼ of the length of the total small bowel, as in his second experiment.

Mall's [2] work was done about the same time as Kirstein's. He also found that at the upper anastomosis there regularly developed dilatation and hypertrophy, and that in this spindle shaped area, hard foreign bodies tended to collect, though some glass balls fed to such an animal passed through the whole alimentary tract. Faradic stimulation (2 mos. p. op.) in one

[1] Deutsche Medizinische Wochenschrift, p. 1000, 1889.

[2] Johns Hopkins Hospital Reports, p. 93, 1896.

case in which he employed it, showed no reversal of the peristaltic waves.

F. Kauders [3]—1893—repeated these reversal experiments in cats, but failed to obtain any adequate results from his study of the peristalsis of the reversed loop, as only the circular muscle fibres contracted. He thought that Kirstein's conclusions were incorrect, that the bowel contents were squirted through the reversed loop which was passive. He made this more than bold criticism despite the fact that in Kirstein's case (No. 2) ¼ of the small gut was reversed. To imagine a force adequate to squirting food, etc., through ¼ of the length of the small bowel, requires more than an ordinary effort.

W. Edmunds and C. A. Ballance [4]—1896—repeated these reversal experiments, and though their work throws no light on the question of anti-peristalsis, they call attention to the fact that the reversed loop became shorter in their cases.

G. Kelling [5]—1900—published one reversal operation in the uppermost jejunum. Three and one-third months after this operation he opened the animal's abdomen, and made a more or less satisfactory study of the peristalsis of the reversed loop. He incised the lower end of the loop, and saw the contents moved towards the rectum by distinct peristaltic waves! This animal was alive and well 1⅓ years after the operation.

Muehsam [6]—1900—contributed a great deal to this subject by bringing further evidence based on the second method of studying this problem—evidence along the same lines as Kirstein's, but perhaps more conclusive. He reversed practically all the small gut (430 cm. out of 485 cm.), and the animal lived 22 days, having occasional attacks of vomiting, and regular defecations. In the defecations, he recovered charcoal which had been fed by mouth 18 hours earlier. This unique case can in our opinion, be explained in only one way, by a reversal of the peristalsis in the reversed intestine.

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[3] Centralblatt f. Physiologie, p. 222, 1893.

[4] Medico-Chirurgical Transactions, London, vol. 76, 1896.

[5] Langenbeck's Archiv., p. 326, Bd. 62, 1900.

[6] Mittheilungen aus d. Grenzgebieten d. Medizin u. Chirurgie, vol. 6. 1900.

(*Prutz and Ellinger* try to explain the phenomena here observed as the result of the action of the surface currents originally described by Grützner, to which reference has been made above.)

In 1901 *Enderlen and Hess*[7] experimented along these lines, and in one case made a study of the peristalsis in the reversed loop. By faradic stimulation, a peristaltic wave was produced in the reversed direction from normal, *i.e.*, the peristaltic wave was reversed in the reversed loop.

In 1902, Prutz and Ellinger[8] reviewed the whole subject, and did further experimental work along the same lines. In one case they observed the peristalsis in the reversed loop, 31 days after the operation, and found that it was not reversed. They admit, however, that occasionally anti-peristaltic (reversed) waves were seen in the reversed, and in the non-reversed bowel. In all their 12 experiments this is the only observation or study of the peristalsis of the reversed loop. They, however, attempted to determine by other means, in which direction the peristaltic wave progressed. By producing a stenosis in the lower part of the reversed loop, and noting on which side of this, dilatation developed, they thought they could discover the direction of the wave. Thus if the peristalsis were reversed, dilatation would occur above the stenosis; if not reversed, dilatation would develop below the artificial stenosis. In 2 cases they obtained results which they interpret as showing no reversal of the peristaltic wave. In our opinion, they have gone beyond the data which they have published, and to us it seems as if their conclusion was not only unwarranted, but in view of the fact that the dilatation above the artificial stenoses was regularly much greater than that below, a conclusion, the direct opposite of theirs, seems justifiable.

This brief review shows how at variance the different results are. Most of the experimentors failed to study the peristalsis in the reversed loop. Some attempted such a study, but invariably only in one case. This most conclusive method of deciding the problem before us has been signally neglected.

[7] Deutsche Zeitschrift f. Chirurgie, p. 240, 1901.

[8] Langenbeck's Archiv., p. 964 Bd. 67, 1902.

The second method of investigating this question, Kirstein and Muehsam used successfully by making very extensive reversals.

In our work done on dogs, some 20 experiments in all, we employed both methods of investigation, and our results will be grouped according to the method employed. We operated in the usual way, cutting out a segment of small gut or large gut and then reversing it. The anastomoses were either end to end, or lateral. The latter was preferable when very large segments were reversed, as there was apparently, less direct tension on the suture line by opposed peristaltic waves, and consequently less chance of leakage. No matter how carefully the operation was done, leakage and separation at the upper anastomosis would occasionally develop so that we were inclined to conclude that the bowels of different dogs varied in their irritability, and perhaps in their muscular strength to such a degree that the technique that was adequate for one might prove inadequate for another, when the opposing and perhaps obstructive peristaltic waves caused undue pressure against the upper anastomosis. At the lower anastomosis, such leakage was most exceptional despite the fact that the direction of the peristaltic waves was probably in opposite directions, *i.e.*, tugging at the anastomosis.

In all animals that survived the operation, we did not make studies in peristalsis, as we were interested in other problems connected with this work, and did not wish to sacrifice all to this study. In the following pages we trust, however, we have sufficient data to warrant the standpoint we have taken.

SERIES I.—*Direct Inspection of Reversed Loop—Small Intestine Reversals.*

No. 84.—Spaniel operated March 15, '06. Median abdominal incision. Reversal of about 15 inches of lower ileum and lateral anastomoses in reversed position, to the bowel above and below lines of section.

March 20. After primary indisposition animal recuperated on diet of milk and biscuits.

May 20. Defecates regularly (practically daily; careful note of this being made every day). Animal began to do poorly.

June 9. Eleven weeks after the reversal a study of the peristalsis was made under ether, the intestines being well protected by very frequent

use of warm saline solution, hot towels, etc. The peristaltic waves were stimulated in a variety of ways, mechanical, chemical and thermal stimuli being employed in the different experiments.

Observation.—The peristaltic wave in the reversed loop was very clearly in the same direction as that of the rest of the small bowel. Peristaltic waves that began above upper anastomosis traveled into the reversed loop and then down this across the lower anastomosis. Peristaltic waves which began in the reversed loop traveled to a slight extent upward, but in the main they traveled downward and then frequently across the lower anastomosis.

Autopsy showed in addition to some adhesions which produced slight kinking of the bowel, well marked dilatation and some hypertrophy of the lower end of the gut above the upper lateral anastomosis. The reversed piece was very slightly dilated and contained two large fecal masses.

No. 41.—Fox terrier had been frequently operated, *i.e.*, gastroenterostomy, gastrotomy before reversal was done.

March 8. After breaking up a lot of adhesions 24 inches of lower ileum were reversed and united to the rest of the bowel by end to end anastomoses.

April 1. Animal except for occasional vomiting did fairly well. By adding milk to his biscuit diet his condition was improved. Defecates regularly.

April 24. Six weeks and five days after the reversal the abdomen was opened to study the peristalsis as in the previous case. The exposure was difficult because of adhesions.

Observation.—The bowel proximal to the upper end to end anastomosis was found markedly dilated and hypertrophied for 6–8 inches. The upper part of the reversed gut for 1–2 inches was similarly changed. The rest of the reversed bowel—the lower anastomosis and the bowel below were unchanged. The reversed loop was empty, whereas the parts adjacent to the upper anastomosis were full of intestinal contents. In studying the peristaltic waves great difficulty was met with in determining which way they progressed. Above the upper anastomosis the wave was katastaltic, *i.e.*, in the normal direction, while in the reversed loop mechanical stimulation as well as heat evoked once a peristalsis in one direction and at another time in the opposite direction. In the lower part of the reversed loop the direction of the peristaltic wave was more distinctly downward. Abdomen closed.

May 12. Nine weeks and two days after reversal, abdomen opened.

Observation.—After separating adhesions in abdomen, we attempted to stimulate peristalsis without any further manipulation of the bowel. Croton oil was injected into the lumen without results; local application of salt produced only localized circular contractions. Hot saline solution produced well-marked peristaltic waves, which could be seen beginning above the upper anastomosis, traveling across this anastomosis and continuing down the reversed gut. In this loop the circular muscle contractions were well marked. The progression of the peristaltic waves were distinctly from upper to lower anastomosis. The bowel was almost empty. Animal killed.

No. 90. Pug. On March 22d between 12 and 15 inches of lower ileum were reversed and end to end anastomoses (Maunsell method) were made. The dog was carefully fed on milk, meat and biscuits so that he might continue in good health for a long time.

October 23. Seven months after the reversal the abdomen was opened.

Observation.—There was marked dilatation above upper union for at least 15 inches. This piece of bowel was also hypertrophied. In the region of the upper anastomosis there was an accumulation of stones. The reversed loop was slightly dilated and markedly hypertrophied. The peristaltic waves were distinctly downward in the reversed loop.

SERIES II.—*Colon Reversals.*

No. 76.—On March 10, 1906, as much of the ascending colon as could be liberated—about 6 inches—was resected and reversed and then reunited by end to end anastomoses to the rest of the bowel. This case did well on the selected diet.

January 4, 1907. Almost ten months after operation the abdomen was opened and a study of the peristalsis was made.

Observation.—The reversed loop was dilated and hypertrophied. The peristaltic waves descend from the ileum across the upper anastomosis and then descend through the reversed loop, but stop at the lower anastomosis. Circular contractions follow each other in the reversed loop, in the same direction as the composite peristaltic wave. The reversed bowel contains foreign bodies.

These observations of the behaviour of the reversed loops leave no doubt in our minds that the small and the large bowels are capable of propelling food in an anti-peristaltic direction. It would appear that the bowel has a distinct power to work in an anti-peristaltic direction and moreover that this power is capable of extensive development. Early in the life of the reversed loop, there seem to be ana- and kata-staltic waves; later on the kata-staltic (which are anti-peristaltic with reference to the original normal bowel) seem to predominate. We are inclined to agree with Kirstein, that in the reversed loop, the peristaltic waves vary in direction, especially at an early stage in the life of the reversed loop, and that is well shown by Case 41, at the first study of peristalsis. Prütz and Ellinger's observation of anti-peristaltic alternating with isoperistaltic waves in their one case, seems to us to fit into this view of the matter. Perhaps Mall's observation will bear a similar interpretation which harmonizes the divergent results summarized above. To what extent the reversed bowel moves kata-staltically with abdomen closed, we can not say as yet.

Just why a more or less spindle-shaped dilatation develops at the upper union is not very clear to us. At first one would jump at the explanation usually offered—that there is an obstruction due to opposed peristaltic waves and that leads to dilatation and hypertrophy at this point.[9]

That some truth is contained in this explanation, in view of the fact that foreign bodies tend to collect in the lumen at this point, and in view of the observation made by Cannon and Murphy mentioned further on, we can not doubt, though we feel sure it is not the complete explanation, as the same obstruction would, we think, be manifested throughout the length of the reversed loop, still the loop as a whole does not dilate and hypertrophy.[10]

If we now turn our attention to the second or inferential method, *i.e.,* the reversal of very big segments of the bowel, we find that with reversal of the whole jejunum and ileum, most animals die of a perforative peritonitis due to leakage at the upper union. Those animals that live long enough to be of any value, behave much as Muehsam's case, defecating repeatedly after the first day or two, without any marked vomiting. These animals, probably because of the great change in the intestinal chemistry, digestion and absorption being rudely interfered with, die very suddenly. For instance, one animal thus operated on did well in every respect for five days and then died suddenly without any definite gross lesions to demonstrate the cause. Another died suddenly 10 days after operation, a few hours after receiving a good dose (½ ounce) of castor oil. This animal at autopsy had a fresh invagination at the lower anastomosis which occluded the bowel.

But it is not necessary to rely on such extreme cases alone. It is sufficient to reverse some 15–24 inches, as we did in a large number of cases. For it is inconceivable that an animal can defecate regularly, if such a length of reversed bowel does not, at least from time to time, function kata-staltically. In

[9] The fact that this dilatation develops very early lends support to this view.

[10] The colon may behave differently from the small intestine—the whole loop apparently dilates and hypertrophies here.

the cases quoted above, such resections have been made and the animals lived in fairly good health and defecated practically every day, provided they were carefully fed. To cite further cases, from our lists, of prolonged life with regular bowel activity after such reversals would not be of any value. We regret that we could not duplicate Muehsam's case and keep an animal, with reversal of all the small intestine, alive for over three weeks.

Thus both groups of observations point to the conclusion that the intestines both large and small, are able to propel their contents in an anti-peristaltic direction.

Further evidence of the truth of this conclusion is furnished by the excellent observations of Cannon andMurphy,[11] who observed anti-peristalsis in the duodenum, a portion of the intestine that we could not experiment on. In a reversal experiment, where the jejunum was reversed close to the duodenum, they repeatedly saw, 6 days after operation, with the aid of the X-ray, that food left the pylorus and descended to the upper anastomosis and then was in part rapidly moved back again towards the pylorus. This unique observation makes it equally clear that there is a more or less marked obstructive condition at the upper anastomosis in these reversal experiments.

Cannon's earlier work on the peristalsis of the ascending colon of cats, shows without a doubt that Jacobi's[12] observation of anti-peristalsis in this part of the bowel (and in lower ileum in colchicin poisoning) was well founded. Here it would seem that this is a normal process,[13] whereas our experiments do not take us that far, any more than those well known experiments of Nothnagel, in which he produced anti-peristalsis in the bowels by abnormal stimuli, such as injections of concentrated salt solution.

In addition to all this experimental evidence, we dare not disregard the clinical evidence which so frequently has to be

[11] Annals of Surgery, 1906.

[12] Archiv. f. Exp. Pathologie u. Pharmakologie, vol. xxvii, 1890.

[13] Except in dogs. T. R. Elliott and E. Barclay Smith, Journal of Physiology, xxxi, 1904, p. 273.

taken with a grain of salt. In this paper we shall not go into this matter in any great detail, as our main object was to present our experimental results; still for completeness sake we must briefly mention the clinical evidence in favor of an affirmative answer to our postulated query, at the head of this paper.

Fecal vomiting in intestinal obstruction and the vomiting of fecal masses and enemata in so called hysterical patients, excluding of course actual cases of fraud can be most readily explained by this ability of the bowel, especially marked under abnormal stimuli of propelling their contents in an anastaltic or antiperistaltic direction.

These two types of fecal vomiting must be distinctly separated, as the former is explicable in several ways whereas the latter in our opinion is subject to but one explanation. In the vomiting of intestinal obstruction, the fluid contents of the bowel may be squeezed out of the bowel into the stomach, thence to the outer world by the pressure exerted by the forceful contractions of the abdominal muscles—anti-peristalsis may have nothing to do with it. Cannon and Murphy's observation, above referred to, makes us believe however, that antiperistalsis is an important factor in this process, the more so as all of the bowel above an obstruction is not regularly well filled at autopsy of ileus cases, as the explanation based on hydrodynamics would demand. It appears to us, therefore, that both forces work together in producing this symptom.

The vomiting of formed feces and the vomiting of enemata a few minutes after introduction into a normal alimentary tract, as reported by Treves, Langmann [14] and others, cannot be explained by anything short of a most active antiperistalsis of the whole bowel. In this we consider Nothnagel's verdict final, despite Wilms' recently expressed scepticism. The former says in his discussion of those cases, so called hysterical ileus cases, "that in no other way can this vomiting be effected than by well marked, in part even very active antiperistalsis of the intestine."

[14] A. Jacobi, Festschrift, 1900, N. Y.

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COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY, NEW YORK

Department of Surgery

OBSERVATIONS UPON A FORM OF DEATH RESULTING FROM CERTAIN OPERATIONS ON THE DUODENUM AND JEJUNUM [1]

With the Determination of a Lethal Line for Experimental Purposes

By J. W. DRAPER MAURY, M.D.

Instructor in Experimental Surgery at the College of Physicians and Surgeons, Columbia University, New York; Fellow of Rockefeller Institute

IN the course of conducting some experiments intended to determine the efficacy of the twine triangular ligature for gastroenterostomy (*Annals of Surgery*, June, 1905), we were led to employ it after the duodenum in the pyloric region had been cut and invaginated. By this method the stomach was shut off from the lower gut for seventy-two hours, the time required for the triangular stitch to cut through. The immediate occasion for our doing this work lay in an attempt to verify Mayo's suggestion, that, given a stoma of any size and made by any method, it would tend to contract unless the pylorus were closed. Given, in other words, a natural and an artificial opening in the stomach, nature's processes might be depended upon to close the latter if the former remained patent. A half-dozen dogs were operated upon in this manner, but, to our discomfiture, and contrary to our expectations, the entire series died consecutively. Death took place in from twenty-four to forty-eight hours, preceded by tetanoid symptoms. It is regrettable that more extensive clinical *data* bearing on post-operative conditions are not available. Observations of any value were most difficult to make, because of the suddenness of the advent of the symptoms and the speed with which the animals died. It can therefore be stated in a general way only that these dogs recovered well from the operations, suffering apparently but little from shock. They behaved much as dogs operated upon in any usual manner, until from four to six hours before death. At that time, they began to show weakness in the hind legs, and the pulse, in all observed cases, rose with the advent of the symptoms to 180 and over. They showed no evidence of pain. Even before death there was marked stiffness, and immediately after death a well-defined rigidity was present.

At first we thought that our dogs were dying from shock, owing to poor technique, or to the fact that they had not been long enough habituated to the hospital environment. Continued experimentation, however, showed these suppositions to be groundless. Autopsies made in the ordinary manner failed to reveal anything. There was only very moderate dilatation of the stomach, and in no case was peritonitis or any form of sepsis present.

Having therefore determined that death was due to some more subtle factor than those considered, we decided, first, to find the line on the small intestine at which section and invagination might be made without gastric drainage for seventy-two hours; and second, to make certain, by varying our experiments, that we were dealing with unusual lethal factors, and had not been deceived merely by coincidence.

As the subject is a difficult one to discuss, it will be made more clear by stating now that this line was found to be about thirty-five centimeters from the pylorus. We named it the lethal line, and understand it to be situated at that point in the jejunum distal to which the gut may be blocked for seventy-two hours without killing the animal. In all our experiments the twine triangular stitch was so placed as to create a gastroenterostomy. Experimentation has shown this to be patent, on an average, in seventy-two hours.

The experiments herewith detailed are not

[1] This research was conducted under a fund from the Rockefeller Institute, at the Surgical Research Laboratory of Columbia University.

consecutive. They have been chosen simply to illustrate certain points under discussion.

WAS SHOCK A FACTOR IN CAUSING DEATH?

Having then decided that death must be due to some more subtle factor than those above considered, we began to perform the operation already cited, in two stages, separated by seventy-two hours. The twine triangular stitch was inserted at the first operation as shown in Fig. 1, and the duodenal section shown in dotted line near the pylorus was made at the second sitting. Dogs operated upon in this manner developed only moderate reaction, and exhibited none of the peculiar symptoms evidenced by those animals in which drainage was not already established between the duodenum and the stomach at the time of pyloric section and inversion. Some of the specimens obtained from animals operated upon in this way were exhibited in the pathological section of the American Medical Association during its recent meeting in Atlantic City, and the suggestion was then offered, that the fatal issue, which invariably followed if the work were done at a single sitting, might have been due to toxic causes. Lawson Tate (*Annals of Surgery*, February, 1896) corroborates the statements made at that time, and assumes that animals operated upon in this fashion die of a form of toxæmia. It thus becomes evident from the observations of others, as well as from our own, that certain operations upon the proximal extremity of the small gut produce obscure pathological conditions which have a lethal termination.

DO THE BILIARY AND PANCREATIC SECRETIONS PLAY AN IMPORTANT PART IN THE LETHAL PROCESS?

Although this difficult question can be answered by prolonged experimentation only, some light may be thrown upon it by the observations made, which showed that no apparent difference was evident, at least from the clinical manifestations in the animal, between those cases in which the first part of the duodenum was infolded proximal to the entrance of the biliary and pancreatic ducts and those in which this operation was done distally to them. In other words, it seemed to make no vital difference whether the biliary and pancreati secretions were emptied into the proximal o into the distal segment; all animals operate on in the immediate neighborhood of th pylorus and ducts died with identical clinica symptoms and in approximately the sam time.

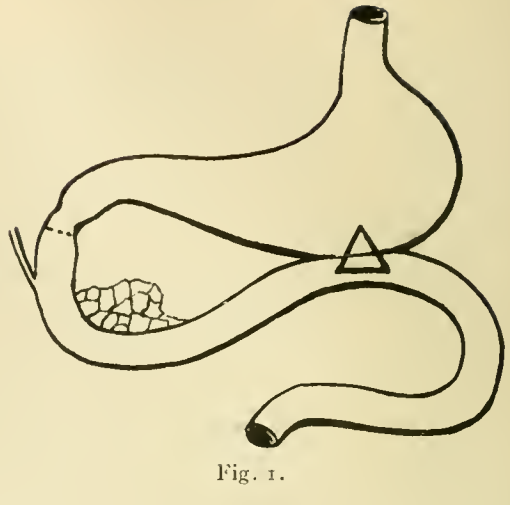

Fig. 1.

WHAT IS THE EFFECT OF DUODENAL SECTIO EIGHT TO TEN CENTIMETERS FROM TH PYLORUS?

Fig. 2 is a rough graphic outline of the nex stage of the work undertaken to answer thi question. The duodenum was cut and invagi nated about ten centimeters distal to the pyloru (P). This region was found very convenien to work in, because for a short distance in dog the gut is sufficiently free from the pancrea and from the transverse mesenteric fold to giv operative freedom. The only difference note in the death of animals operated on in thi manner and those in which the duodenal sec tion was made nearer the pylorus was, that, i general, exitus subvened a few hours later, an the tetanoid symptoms seemed a little les characteristic. The following experiments ar illustrative:

Dog No. 33. Series 1904–05. December 19, 1904 Kammerer incision to left of median line; duodenun cut and invaginated ten centimeters distal to pylorus twine triangular gastroenterostomy. December 21st dog died fifty-six hours after operation, having mad good operative recovery. Tetanoid symptoms not s marked as in cases cut nearer to pylorus. Ther was a little vomiting of dark brown fluid. *Autopsy* Stomach not at all dilated; no signs of adhesions o peritonitis; stoma not open. The bile-duct emptie into the gastric (proximal) portion of the duodenum and was unobstructed. Length of duodenum fron

nvagination to pyloric valve was 5½ cm. An unusual amount of gut had been turned in.

HAS ABSORPTION OF RETAINED FOOD PRODUCTS ANYTHING TO DO WITH THIS FORM OF DEATH?

Still in the dark as to the cause of death, we urned to Dr. Simon Flexner. At his suggesion, the dog was given a large dose of castor-oil, ed on milk for three days, and then allowed o fast, with water, for two days.

Dog No. 38. January 12, 1906, 4:15 P. M. After aving been prepared in the above manner, the abdonen was opened by usual intermuscular incision; the luodenum was divided and ends infolded just distal o entrance of bile-duct. Twine triangular gasro enterostomy. Dog reacted well. January 13th, wenty hours later, the dog was fairly bright, able to tand, but weak in hind legs. Pulse could not be felt n extremities. It had been good after operation. Heart tumultuous and irregular, 180; rectal temperature 7° C. January 14, 8:30 A. M., dog found dead; ody still warm. *Autopsy:* Negative; alimentary canal ractically empty. Fasting dogs die in same manner s feeding dogs.

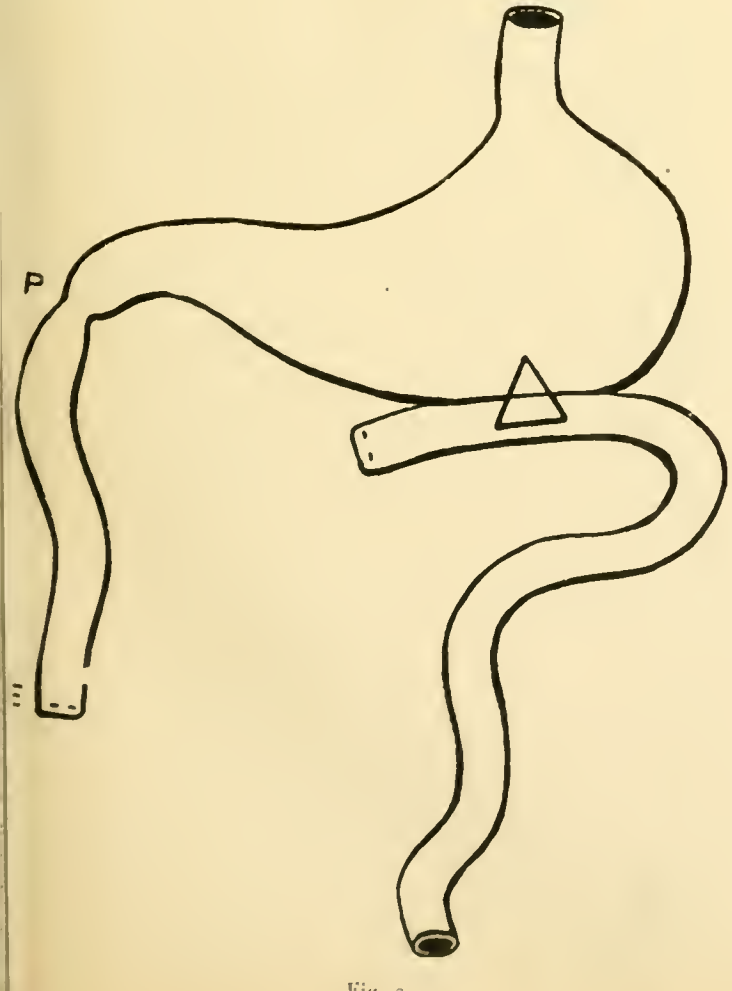

Fig. 2

Dog No. 46. February 4, 1905. This dog was not allowed to fast. The length of the pyloric loop was increased. Roux gastroenterostomy, with twine triangular control, proximal loop 25 cm. in length. February 5th, dog vomited very frequently, but was otherwise apparently in good condition. February 6th, dog died at 11 o'clock, forty-eight hours after operation. *Autopsy:* Cause of death not apparent; no peritonitis.

There seemed to be a constant ratio shown between the length of the proximal loop and the number of hours which the animal would live.

EFFECT OF OPEN STOMA WITH PROXIMAL LOOP TEN CENTIMETERS IN LENGTH

An effort was made to show the effect of using the Murphy button, in the hope of getting an open stoma in place of the twine triangular ligature.

Dog No. 87. March 20, 1906. Intermuscular incision; duodenum sectioned 10 cm. distal to pylorus and ends invaginated; Murphy button placed between the distal loop and anterior gastric wall. March 21st, dog's condition good. March 22d, dog died last night. *Autopsy:* No peritonitis; proximal end of gut dilated and filled with dark fluid; the stomach filled with similar fluid. No drainage had taken place through the button. A small one was used, and the opening in it had become clogged. Death was due to this fact.

DOES SHOCK HAVE ANYTHING TO DO WITH THE DEATH OF ANIMALS WHEN A TEN-CENTIMETER PROXIMAL LOOP IS CREATED?

Fig. 3 shows the next step attempted in this work. It was taken to prove that shock, in the ordinarily accepted meaning of the word, had nothing to do with this form of death. Just before the twine triangular ligature was tied at the point where enteroenterostomy between the proximal and distal loop was to be established, a knife was thrust through the apposing triangles into the enteric lumina, so that immediate drainage would take place. Ordinarily, of course, drainage would not have been established for at least seventy-two hours. That in this case drainage was immediately established by making this stab wound was shown by the case with which a large probe, piercing the duodenum proximal to the site of operation, was passed through the triangle and into the distal loop. This was done after the ligature was tied.

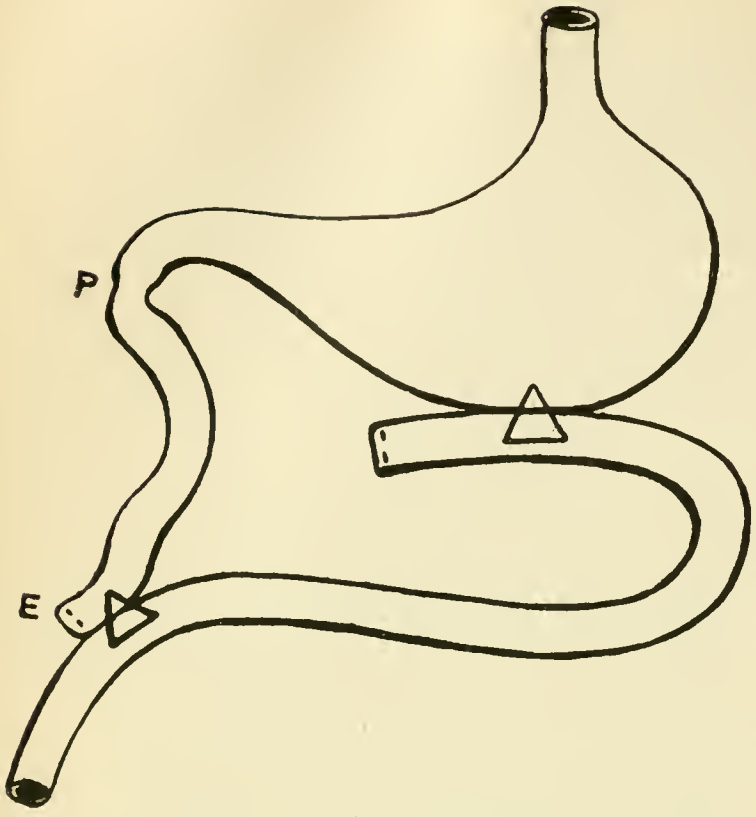

Fig. 3.

Dog No. 52. February 24, 1905. Intermuscular incision, Roux operation; duodenum severed 14 cm. distal to pylorus and ends invaginated; gastroenterostomy between distal loop and stomach, enteroenterostomy with tip of proximal loop, both made with twine triangular stitch; enteroenterostomy triangle stab before suture was tied. March 1st, dog has been in good condition since the operation. He was killed to-day to obtain the specimen. *Autopsy:* Both stomata are cut through; no peritonitis.

As this section was made proximal to the lethal line (since determined to be about 35 cm.), the animal would certainly have died without drainage at the enteric stoma. This type of operation shows that shock has no more to do with death of animals operated on so as to produce a distal loop of ten or more centimeters than in the case of those in which the pylorus itself is closed.

Dog No. 51. February 17, 1905. Intermuscular incision, Roux operation; twine triangular gastroenterostomy was done 35 cm. distal to pylorus. Seven centimeters proximal to this the gut was cut and ends invaginated. The proximal portion of duodenum was connected to distal loop by twine triangular enteroenterostomy, and two stab wounds made in the triangle just prior to the tightening of the twine. The portion of gut extending from the stoma to the distal invagination was left free. February 18th, dog in good condition, although he vomited slightly. February 23d, dog doing very well; shows no effect whatever of the operation. February 24th, dog killed to obtain specimen. *Autopsy:* Both stomata were open. The blind end of the gut had intussuscepted into the stomach showing that in this type of work it ought to be sewed fast to the external gastric wall.

Continued experimentation showed that the stomach might be closed off from the intestine for 72 hours without lethal result, if closure were made approximately 35 cm. from the pylorus. It will be noted that this operation was performed very near to the lethal line. The dog therefore, barring ordinary accidents, had a chance to live, despite the obstruction. Stabbing the triangles at the enteric stoma, however, rendered his living certain.

WHAT IS THE EFFECT OF BLOCKING THE GUT FORTY OR MORE CENTIMETERS DISTAL TO PYLORUS?

Fig. 4 demonstrates the next stage in our work. The jejunum was cut forty centimeters

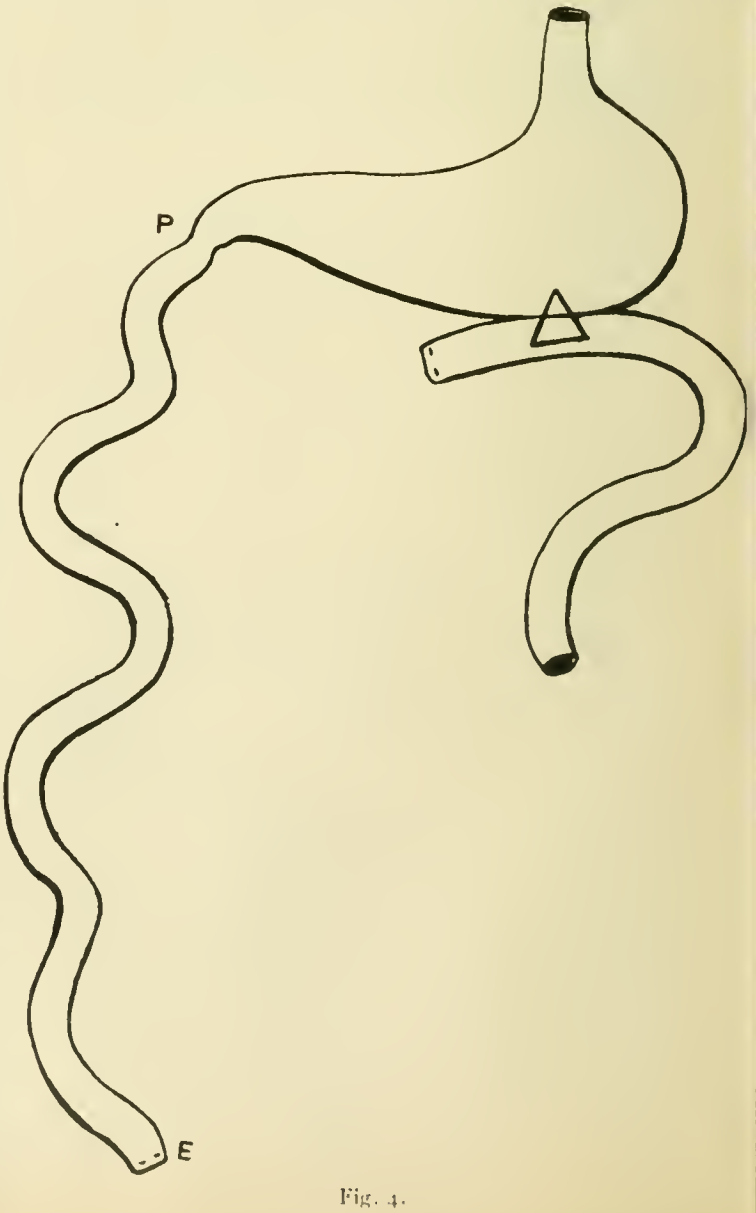

Fig. 4.

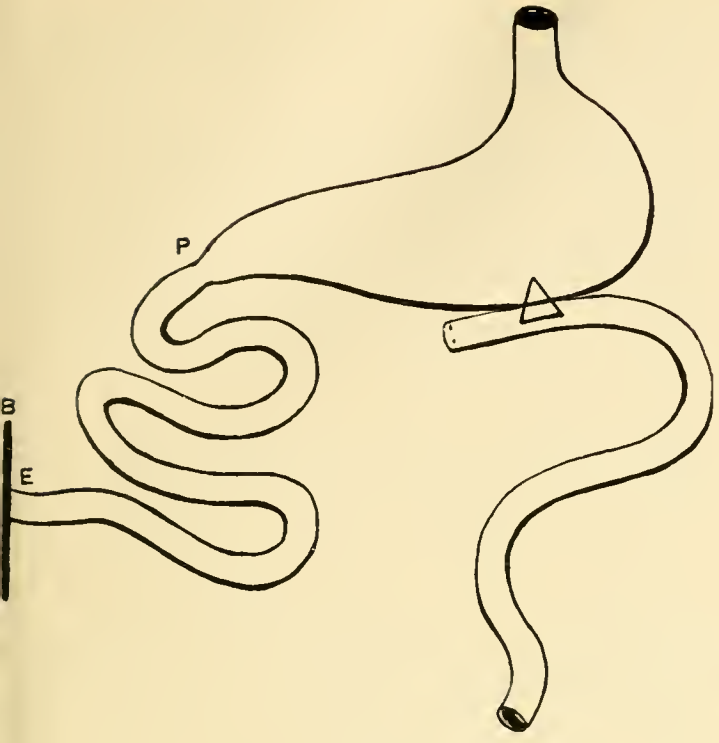

Fig. 5.

distal to the pylorus, and thus about five centimeters distal to the lethal line, and the ends invaginated. Control triangular gastroenterostomy was then done. The secretions were thus retained for 72 hours, and those from the proximal loop were obliged, after that time, in order to reach the lower gut, to pass through the stomach. It seemed hardly reasonable that these animals should live for any length of time.

Dog No. 35. December 31, 1904. Intermuscular incision, gastrojejunostomy, with twine triangular control 40 cm. distal to pylorus. Jejunum then cut proximal to stoma and ends invaginated. December 31st, 5 P. M., dog has not vomited, and seems brighter than those dogs in which the section was made nearer to the pylorus. January 1st, 1 P. M., dog shows no signs of shock or distress, is up and about the cage, trying to get out when door is open. January 2d, noon, dog bright; has not vomited; sits up in cage. January 3d, 9 A. M., dog found dead. *Autopsy:* A leak at the proximal end of the gut had produced a localized peritonitis. The stoma had not yet entirely cut out. Length of post-operative life, sixty hours.

Dog No. 43. January 1, 1905. Intermuscular incision, jejunum cut 35 cm. distal to pylorus, ends invaginated; twine triangular gastroenterostomy with distal loop. January 23d, 3 P. M., dog doing very well; has vomited once since operation; pulse 150; rectal temperature 37° C. Dose of castor-oil; vomited. January 25th, dog not feeling well; has been unwilling to eat since operation; another dose of castor-oil; bowels moved twice. The twine must have cut out. January 28th, dog found dead; was alive last night at 8 o'clock. *Autopsy:* Animal exceedingly thin. There were several small pockets of pus in the peritoneal cavity, but no general peritonitis. Small gut showed seventeen oval areas of pigmentation, bluish in color, with white reticulum; stoma patent, the twine having cut a large opening. Length of post-operative life one week.

Dog No. 72. February 24, 1906. Intermuscular incision; jejunum cut 37 cm. distal to pylorus and invaginated; twine triangular gastroenterostomy. March 3, 1906, dog died, seven days after operation. *Autopsy:* The twine triangular ligature had not entirely separated, but thorough drainage had been established at the angles of the triangle. The proximal end of gut was dilated and filled with a yellowish-green fluid. Length of post-operative life, one week.

Dog No. 78. March 13, 1906. Intermuscular incision; jejunum severed 45 cm. distal to pylorus and ends invaginated; gastroenterostomy by twine triangular ligature between stomach and distal loop. March 14th, dog quite sick; vomited excessively. March 17th, spry and taking food well. March 18th, not so well. March 19th, dog drooping; pulse 150; will not eat. March 20th, dog died last night. Length of post-operative life, one week. *Autopsy:* Proximal loop was a little dilated. There was some local peritonitis around the proximal stump. The ligature had cut through.

Unfortunately, two of these animals had some strictly localized pus-pockets in the peritoneum. Judging from the extent of these, however, it may conservatively be said that they probably had very little to do with the cause of death. All the animals were much emaciated, and behaved more or less as dogs usually do after the establishment of a biliary fistula.

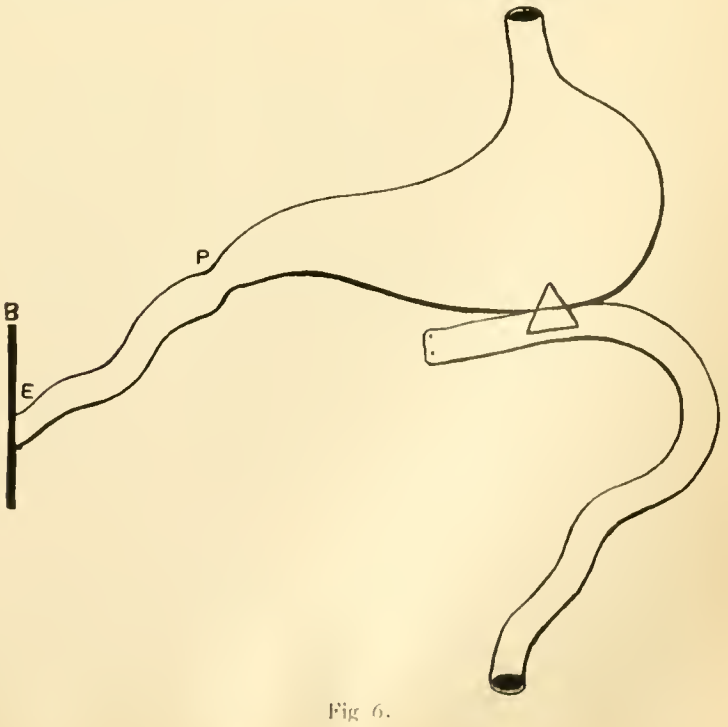

Fig. 6.

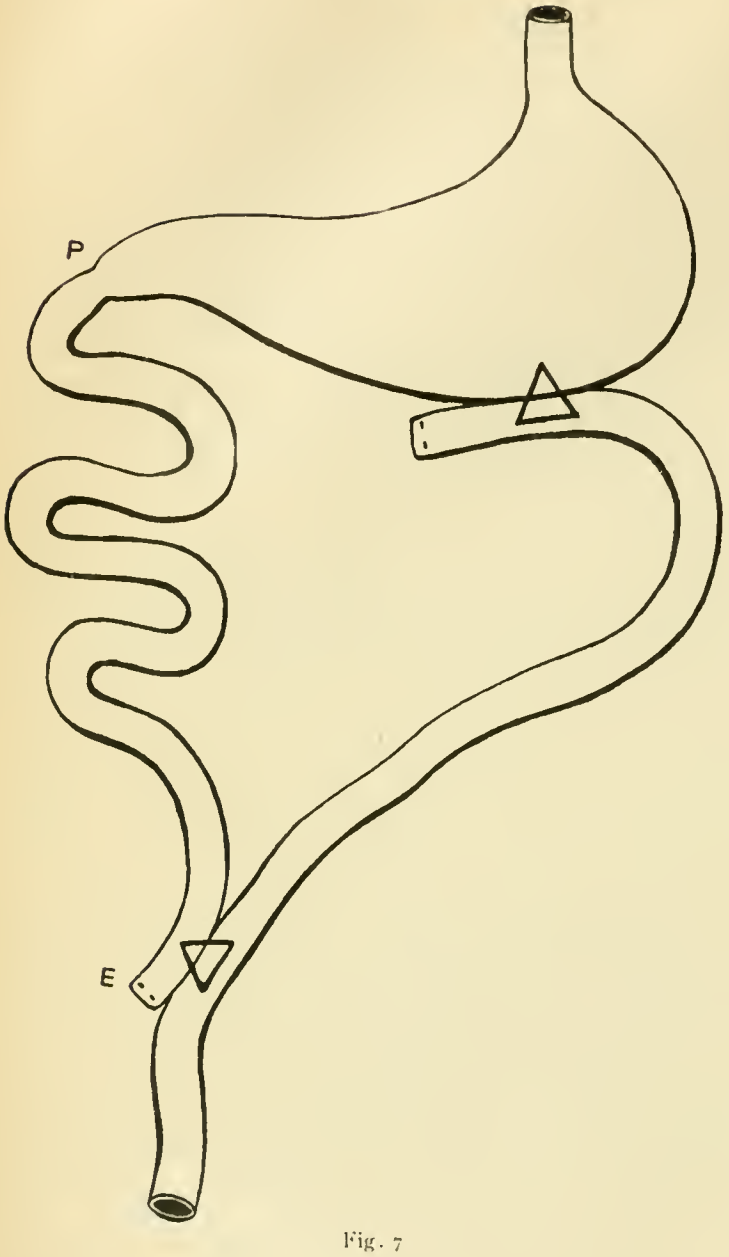

Fig. 7

WHAT EFFECT HAS A COMPLETE LOSS OF THE SECRETIONS UPON THIS FORM OF DEATH?

Fig. 5 represents the type of experiment by which we sought to answer this question. The section of the jejunum was made just beyond the lethal line, and the proximal loop was brought to the surface of the body (B). Twine triangular gastroenterostomy control was done with the distal loop. Thus the secretions, both from stomach and duodenum, were all lost until the twine gave drainage; viz., in about seventy-two hours.

Dog No. 79. March 13, 1906. Intestinal stoma and twine triangular gastroenterostomy. March 14th, dog has vomited a little. March 15th, fistula draining. March 17th, dog feeble, but taking milk. March 18th, stool. Stoma draining; dog does not have great thirst, as when loop is very short, showing absorption of water is taken place freely from the loop (P–E). Dog feeble, but pulse 80; very irregular. March 20th, dog died. Length of post-operative life, one week. *Autopsy:* There was a slight purulent infiltration in the abdominal wall, at the site of the enterostomy, which it was not convenient to do at two sittings. There was also a small area of walled-off peritonitis at the distal stump. The triangular ligature had cut out a free stoma. Death took place in this and like cases at about the same time as if, with a similar length of proximal loop, it had been retained within the belly-wall and simply invaginated.

WHAT EFFECT, IF ANY, HAS A SHORTENING OF THE PROXIMAL LOOP WHICH DISCHARGES UPON THE SURFACE ON THIS FORM OF DEATH?

It seems to have a very considerable effect. If, as in Fig. 6, an animal be prepared by bringing the open duodenum to the surface (B), the loop (P–E) being about ten centimeters in length, and if at the same time the twine triangular gastroenterostomy control be put in, the animal will die with symptoms which seem to resemble those subvening if the pylorus be sectioned and infolded.

Dog No. 77. March 10, 1906. Intermuscular incision and duodenostomy; duodenum cut and infolded twelve centimeters from pylorus; proximal loop brought to surface and sutured to abdominal wall in three layers. Distal loop twine triangular gastroenterostomy control. March 11th, condition good; some vomiting. March 12th, condition good; dog exceedingly thirsty, showing that practically no absorption of water takes place from the stomach. Dog drank over a liter of water this morning; otherwise normal; up and about the cage. March 13th, dog died at 11 A. M. *Autopsy:* No peritonitis. The twine triangular ligature had cut out. Length of post-operative life, three days.

Dog No. 92. March 27, 1906. Intermuscular incision; duodenostomy with twine triangular ligature, gastroenterostomy control. March 29th, 9 A. M., dog sick. All fluids taken immediately discharged at stoma; dog exceedingly thirsty. No absorption from stomach. March 29th, 2 P. M., dog crouching in cage; will not stand up; has taken a little milk this P. M. 6 P. M. dog died. *Autopsy:* Negative.

THE LETHAL LINE IS ABOUT THIRTY-FIVE CENTIMETERS FROM THE PYLORUS

Fig. 7 outlines the type of experiments by which we finally concluded with a considerable degree of definiteness the position of this line. It represents, as already stated, the point at which the gut may be closed for the time de-

termined by the twine triangular ligature (about seventy-two hours) without a fatal termination.

Dog No. 80. March 13, 1906. Intermuscular incision; gastroenterostomy and enteroenterostomy. The jejunum was sectioned and infolded 45 cm. from the pylorus. March 14th, dog doing well, vomited once. March 16th, doing well; bowels moving. March 19th, condition excellent; stool to-day. March 21st, condition excellent. March 30th, no evidence at all of having been operated upon.

Dog No. 85. March 17, 1906. Operation same as No. 80. Dog vomited somewhat during day. Considerable shock after operation. March 18th, vomited, but doing well. March 21st, condition excellent; stools every day. March 30th, dog in normal condition.

It is evident that the secretions, both from stomach, pancreas, liver, and duodenum in animals operated upon in this manner must be retained in the proximal loop and in the stomach for at least seventy-two hours. Whatever may be the cause of the excitation and death under consideration, if this work be done proximal to the lethal line, death is certain to subvene. If distal to it, the animals will live.

This incomplete report is published in the hope that the attention of other observers may be called to this most interesting, intricate, and obscure series of phenomena, and that with their help it may be possible to determine definitely what the cause of death may be. I have not been able to find any literature on this subject, neither have any of my friends been able to elucidate it for me. To them, and to the students who have aided me so materially, and particularly to our student laboratory assistant, Mr. Carl Eggers, I wish to express my thanks.

It has for some time seemed to me reasonable to believe that there might be a relation between this form of intoxication, if such it be, in dogs and the so-called tetany of human beings. Attempts have been made in the course of this work to de-enervate a series of dogs' stomachs. It is found extremely difficult, although I hope it will not prove impossible, to preserve a reasonable amount of vitality in dogs after section of both vagi (the right, in the neck distal to the recurrent laryngeal and the cardiac branches; the left, in front of the cardia), and all the splanchnics as well. The question seems to have resolved itself now into a determination as to whether death is due to an intoxication resulting from a disturbance of the balance of the secretions, which pour so plentifully into the intestine in this particular region, or, as Herter has suggested, through some interference with cerebral circulation, brought about by nervous impulses, the result of the operation.

We are attempting at the laboratory to obtain animals in good, healthy condition after the entire removal of the pylorus and of the duodenum down to the lethal line. We have been leaving a small section of duodenum just where the bile-duct enters, connecting this proximally with the stomach, and distally with the jejunum, 35 cm. distant. The difficulties attendant upon this work are not inconsiderable, but we hope soon to have animals with de-enervated stomachs and others with the duodenum resected, and in each case still strong enough to make further operative work of value.

Given a healthy post-operative dog with de-enervated stomach, it might be possible to prove or disprove the theory that death was due to nervous impulses arising from the site of operation.

Given a healthy duodenectomized dog, it might be possible to determine whether secretin or other secretions from the duodenum itself had anything to do with the cause of death.

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IS DEATH IN HIGH INTESTINAL OBSTRUCTION DUE TO THE ABSORPTION OF BILE?*

BY J. W. DRAPER MAURY, M.D.,
OF NEW YORK,
Fellow of the Rockefeller Institute.

IT is well known that acute intestinal obstruction occurring in the duodenum or oral portion of the jejunum is much more rapidly fatal than a similar obstruction occurring aboral to this portion of the intestine.

A rather careful study of the literature of the subject has failed to show that any definite cause has been discovered for this well known fact, everything to date being suppositional in character. So recent and so high an authority as M. Wilms, whose extensive monogram on ileus has just appeared, in discussing high intestinal obstruction says: "The time in which duodeno jejunal obstruction causes death has only in the rarest instances been prolonged. Death usually subvenes with extreme rapidity. All patients probably succumb to toxic absorption resulting from the decomposition of intestinal and stomach contents."

Starvation and lack of absorption of water, which has been thought by some to be a factor in producing the syndrome of duodeno jejunal obstruction, are hardly to be considered, particularly when one reflects that absorption of water takes place almost entirely from the colon and can therefore not be materially influenced by the position of the obstruction in the small gut. For, as Mayo says, we drink with our great gut and eat with our small. Wilms makes no mention of the possible relationship of the biliary and pancreatic fluids as a cause of death in duodeno jejunal obstruction.

Neither are these the only suggestions which have been offered as an explanation of the phenomena under discussion.

* A Research conducted under a Fellowship granted by the Rockefeller Institute.

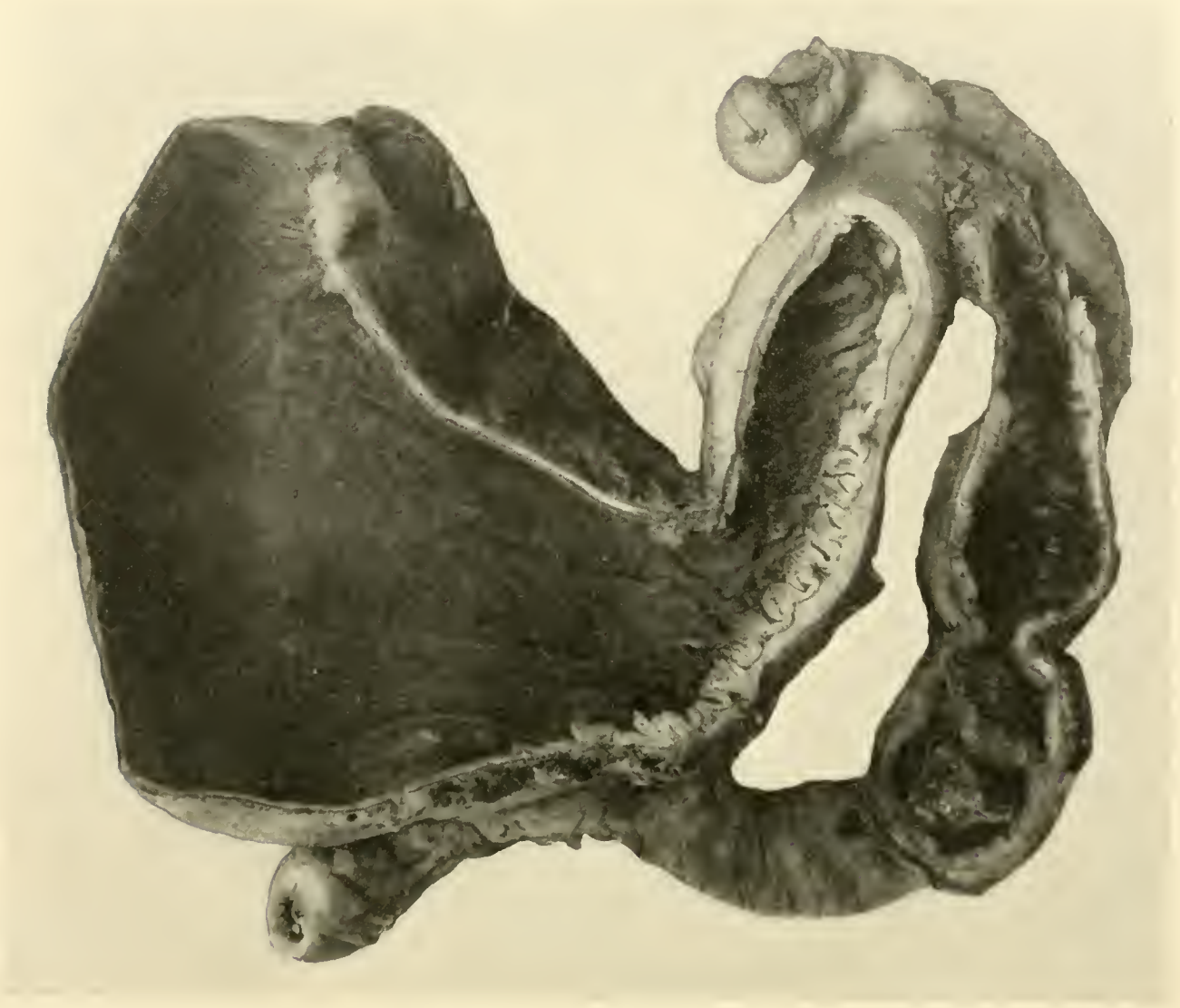
Boszeky and Genersich offer two theories to explain the symptoms in intestinal obstruction, viz., reflex and auto intoxicational. They believe that bacteria and their toxines pass through the intestinal wall; that the slow pulse and other phenomena are caused by the interference with the vagi and splanchnics, which causes congestion of the abdominal organs, thus giving rise to anemia elsewhere, noticeably in the brain. The anuria which is characteristic of this condition is due in the opinion of these two authors to exhaustion of vaso dilators of kidneys and the drop in temperature to exhaustion of the heat centre, all due to cerebral anemia. "But," they continue, "in cases of obstruction by enteroliths, these symptoms cannot be explained on the ground of nervous phenomena. Here it must be chiefly an accumulation of feces and ptomaines and toxines due to *putrefaction of intestinal contents.*"

Here again in an exhaustive German monograph attention is called to the importance of putrefaction of the intestinal contents. Observations which we have made in the Laboratory show conclusively that putrefaction has nothing whatsoever to do with the cause of death in intestinal obstruction, at least when the seat of obstruction is within 35 centimeters of the pylorus.

Accidentally in the beginning, and, more recently, volitionally, we have studied this obscure but exceedingly important problem. It will be necessary in order to make our results clear, to give a short history of the manner in which the subject has been approached.

In a series of experiments conducted in the Surgical Research Laboratory of Columbia University and which were carried on to find some practical method of performing a gastroenterostomy by the so-called closed method, it was noticed that under certain constant conditions the animals operated on invariably suffered a similar train of symptoms which were always followed by a pseudo tetanic form of death. The pathological picture marked by fibrillary muscular twitchings, weakness and later rigidity is not unlike that presented after a parathyroidectomy. The conditions which

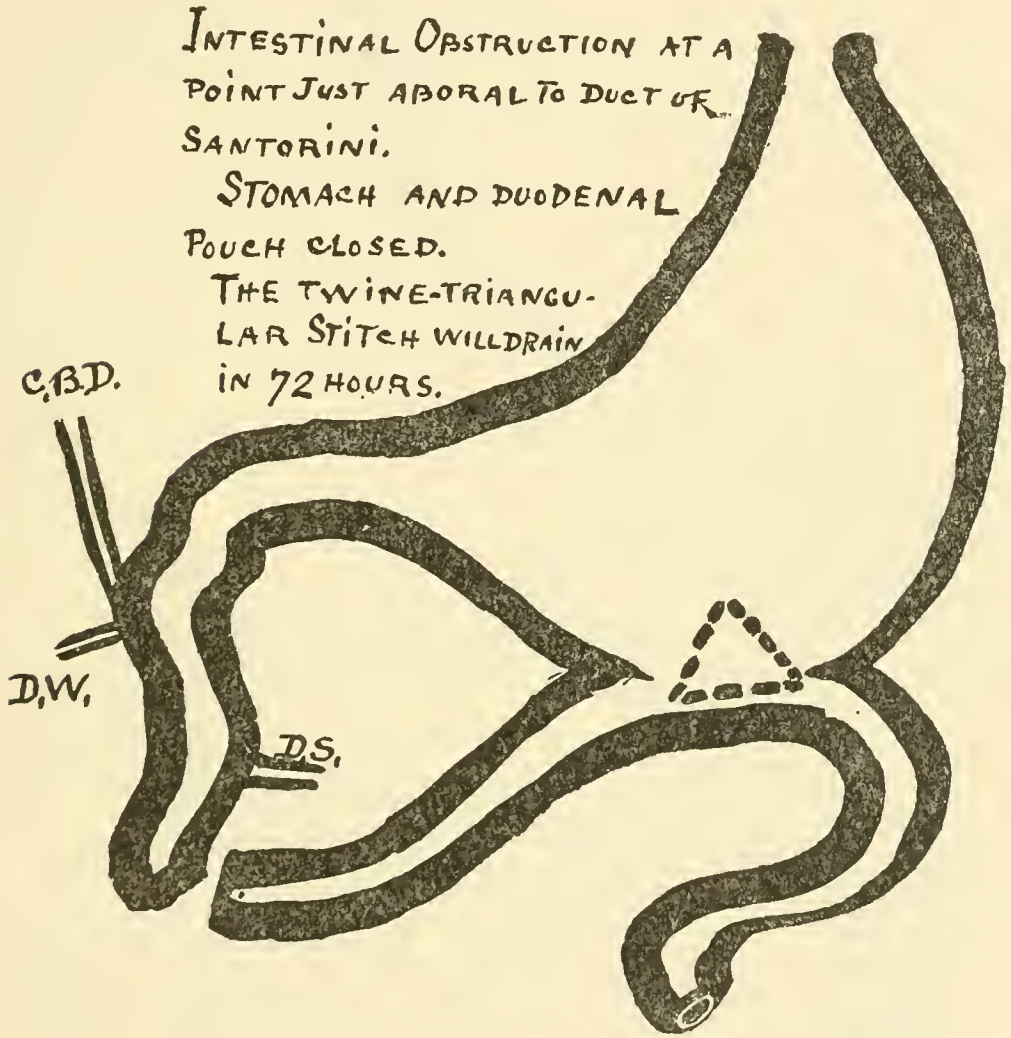
FIG. 2.



Intestinal obstruction. Photograph showing entro-anastomosis (open). Gastro-enterostomy triangular stitch (closed). Animals live if loop be drained. Note the enteroliths which formed in end of intestinal pouch.

united to cause this precise form of death are shown in the accompanying outline (Fig. 1). They consisted in the performance of a gastroenterostomy by a closed method and the severance and closure of the short duodenal loop. The actual technic of effecting the establishment of the stoma is not of immediate concern here. It was made by what has been called

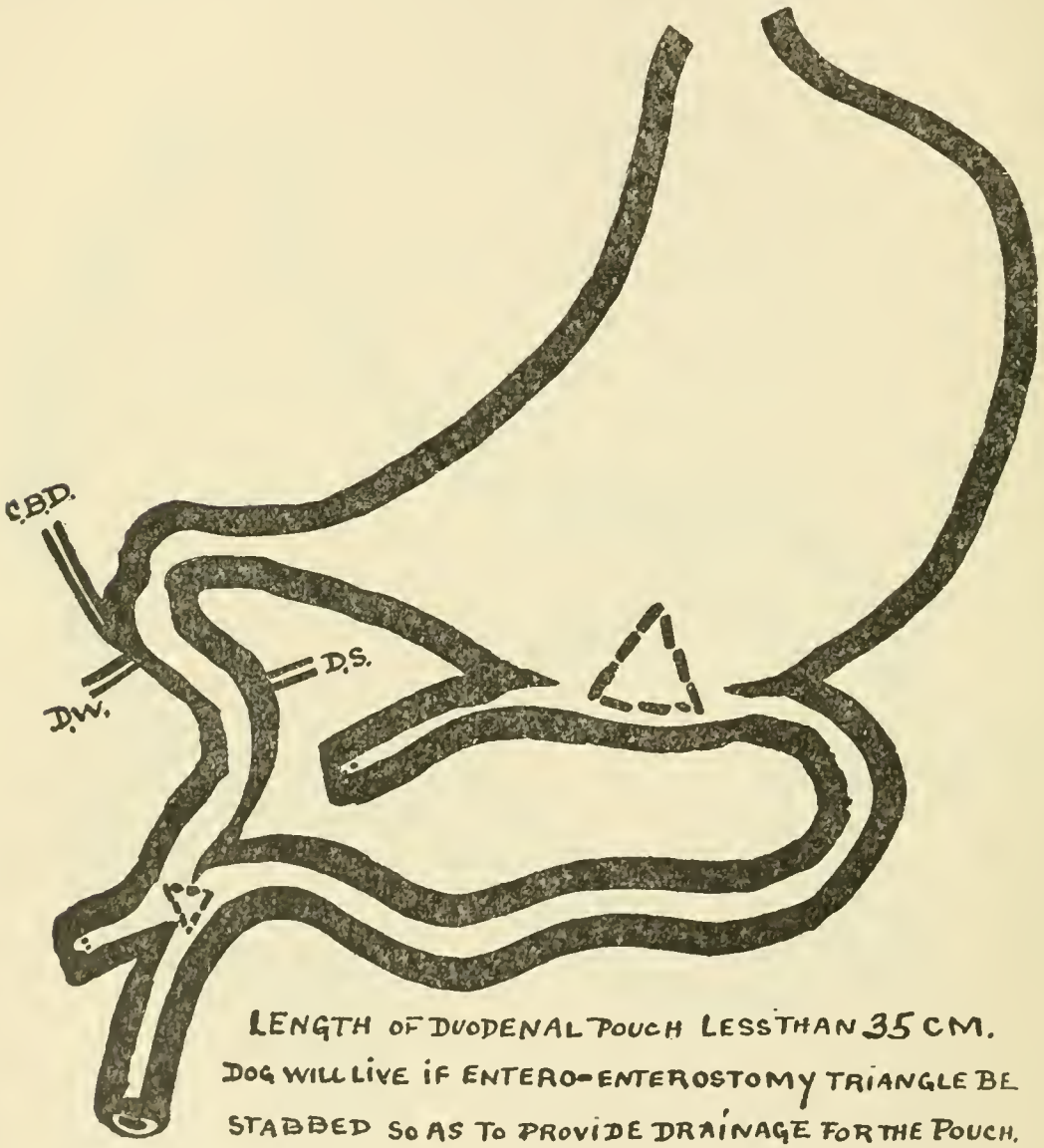
FIG. 1.


INTESTINAL OBSTRUCTION AT A POINT JUST ABORAL TO DUCT OF SANTORINI.
STOMACH AND DUODENAL POUCH CLOSED.
THE TWINE-TRIANGULAR STITCH WILL DRAIN IN 72 HOURS.
C.B.D.
D.W.
D.S.

in previous communications the *twine triangular stitch*. It is necessary, however, to emphasize the fact that this triangular stitch, which is a simple substitute for the McGraw elastic ligature, has been introduced in all the series as a control. It is of great use for experimental purposes when it is desired to close the stomach for a constant number of hours and subse-

quently to have drainage re-established. The twine cuts a punched out opening at a period of from 70 to 100 hours. This varies in different subjects, but in long series a general average will be maintained. This is the first point to make clear.

FIG. 3.


C.B.D.
D.S.
D.W.
LENGTH OF DUODENAL POUCH LESS THAN 35 CM.
DOG WILL LIVE IF ENTERO-ENTEROSTOMY TRIANGLE BE
STABBED SO AS TO PROVIDE DRAINAGE FOR THE POUCH.

In the second place, it was found that the length of the loop from the pylorus to the invagination was the essential factor in determining whether or not the animal would live. It was shown after many tests that if the distance from the infolding to the pylorus was less than 35 centimeters, it would die before

the twine triangular stitch gave drainage (70 to 100 hours). If the loop were longer, the animal would live.

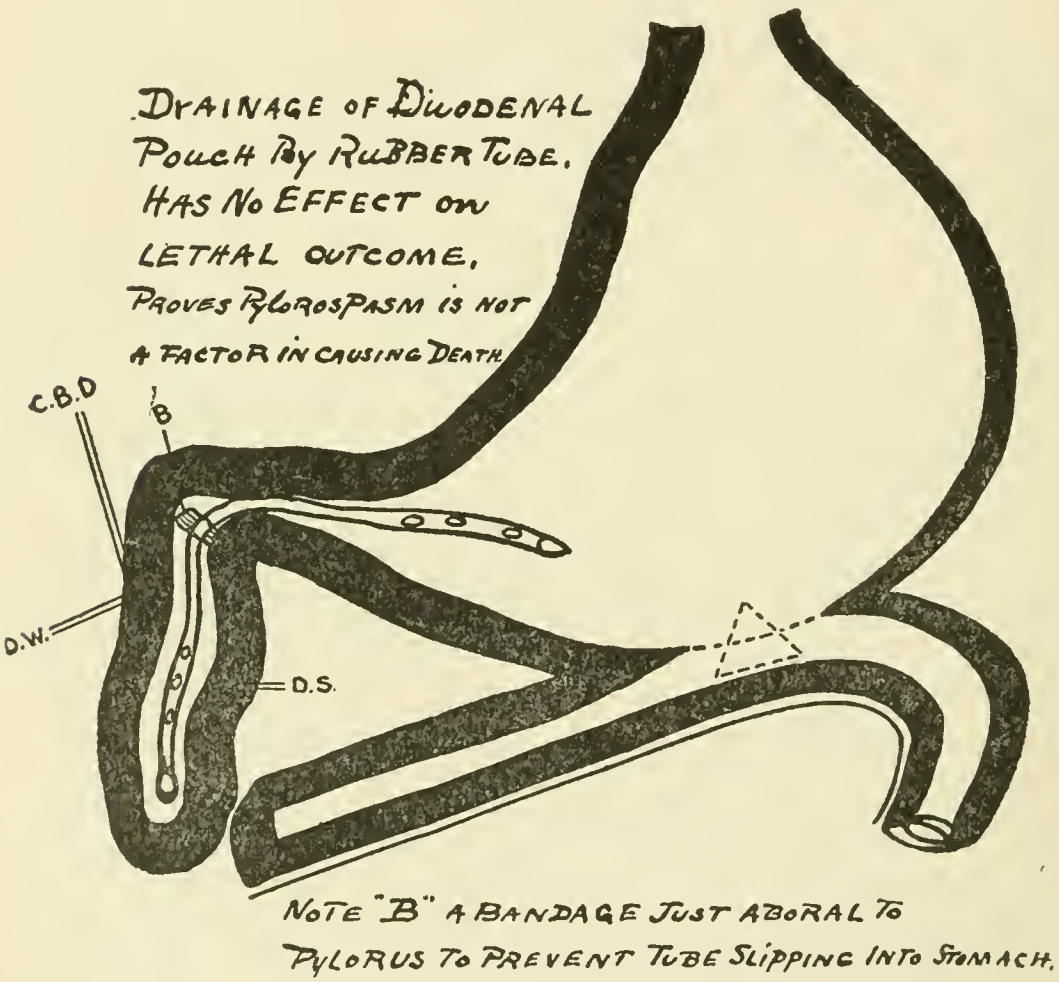
The third point is this: It was suggested by Dr. Flexner that this pseudo-tetanic death might be ascribed to decomposition of food materials in the stomach and duodenal loop. A number of experiments, however, upon fasting animals demonstrated that the presence or absence of food material in the stomach had no effect whatsoever in modifying the influence already alluded to of length of loop. Animals with stomachs well filled and those with alimentary canals thoroughly emptied showed no variation whatsoever in character or rapidity of death. The lethal line in either case was always approximately 35 centimeters from the pylorus.

There was a fourth point of importance. The question arose: Was the disturbance of innervation at the pylorus responsible for the death of the animal? A series of six dogs were operated on in the following manner. The pylorus was either sectioned or resected together with a small amount of stomach, and the ends infolded, great care being taken not to injure the bile duct. Twine triangular ligature was then inserted to create a gastroenterostomy. Without exception these animals lived until after the stoma had been established. This led to a most important conclusion. It showed that if the section and blockage of the duodenum were made oral to the bile duct, so that drainage were maintained for hepatic and pancreatic secretions, the animal would tolerate the absolute closure of the stomach without any ill effect until this viscus were drained by the establishment of the stoma 70 hours later. It is of great import to notice this, for it shows that, the nervous element owing to shock produced by section of the gut in the neighborhood of the pylorus, which has long been recognized to be a serious factor from a vital standpoint, in all operations in this neighborhood has absolutely nothing to do with this form of death which we have described as pseudo-tetanic. It suggests that the biliary or pancreatic secretions, or both, stand in some very definite relation to the lethal results observed. Pseudo-tetanic death occurring so constantly after section aboral to

these ducts and so rarely when the section was made oral to them, is indicative that some profound interruption of normal chemical processes in the intestine produces the fatal result rather than any nervous disturbance or shock.

It should be emphasized that the animals will live with a blocked loop less than 35 centimeters in length if the stoma be made an open one. Drainage of the stomach into the intestines

FIG. 4.


DRAINAGE OF DUODENAL POUCH BY RUBBER TUBE. HAS NO EFFECT ON LETHAL OUTCOME. PROVES PYLOROSPASM IS NOT A FACTOR IN CAUSING DEATH.
C.B.D
B
D.W.
D.S.
NOTE "B" A BANDAGE JUST ABORAL TO PYLORUS TO PREVENT TUBE SLIPPING INTO STOMACH.

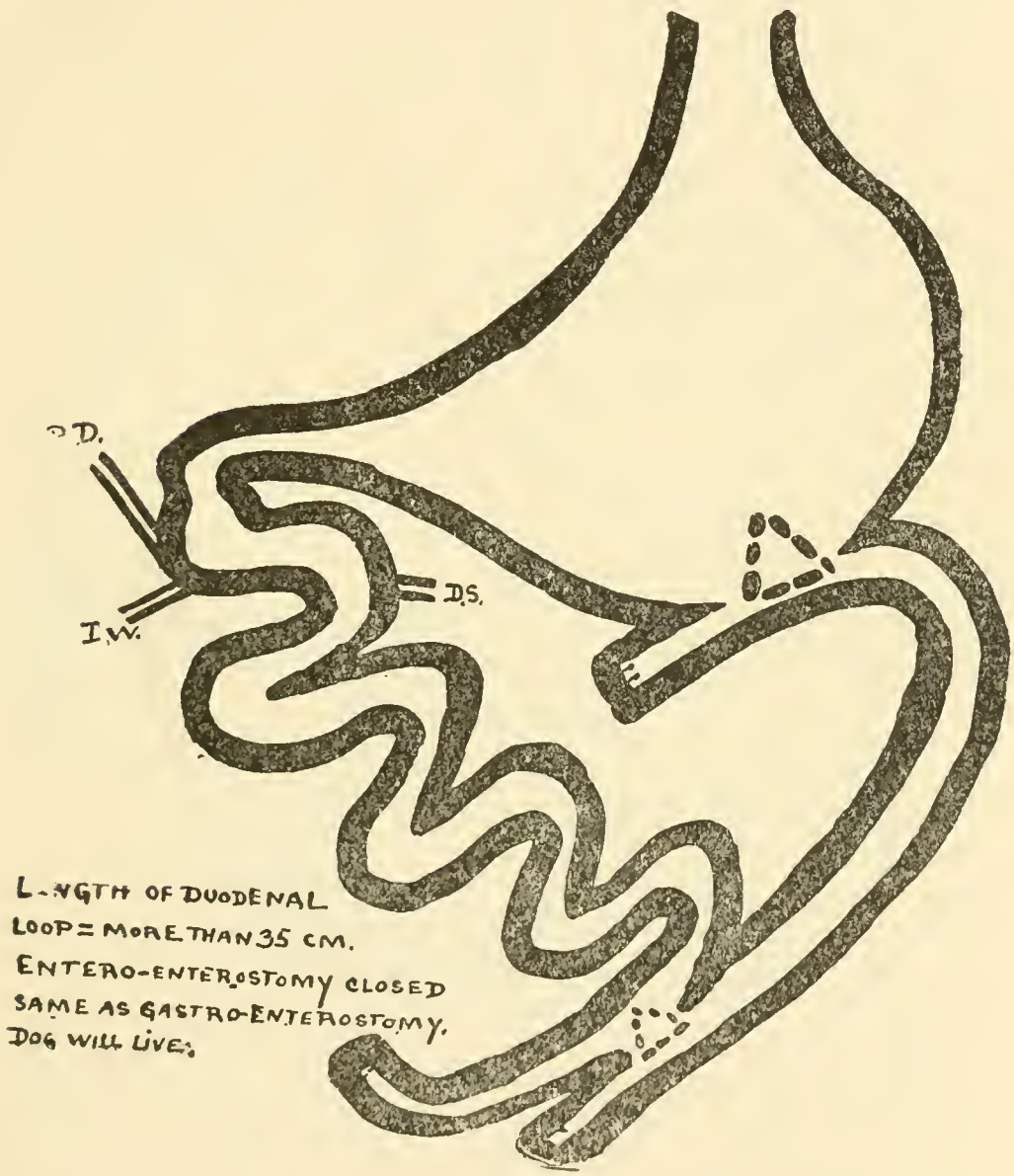
suffices to save the animal's life, no matter where the duodenum may be blocked.

It was further determined that the effect of entero-anastomosis between the jejunum just distal to the gastroenterostomy and the closed duodenal loop just aboral to the entrance of the ducts gave a similar result. Dogs operated on in this manner live. In other words, drainage of the loop is as

effectual in preventing the lethal results as is drainage of the stomach.

Moreover the fatal outcome is not the result of a closure of the loop produced by pylorospasm. The figure (4) shows how the proof of this was obtained. Rubber tubes placed so

FIG 5. .

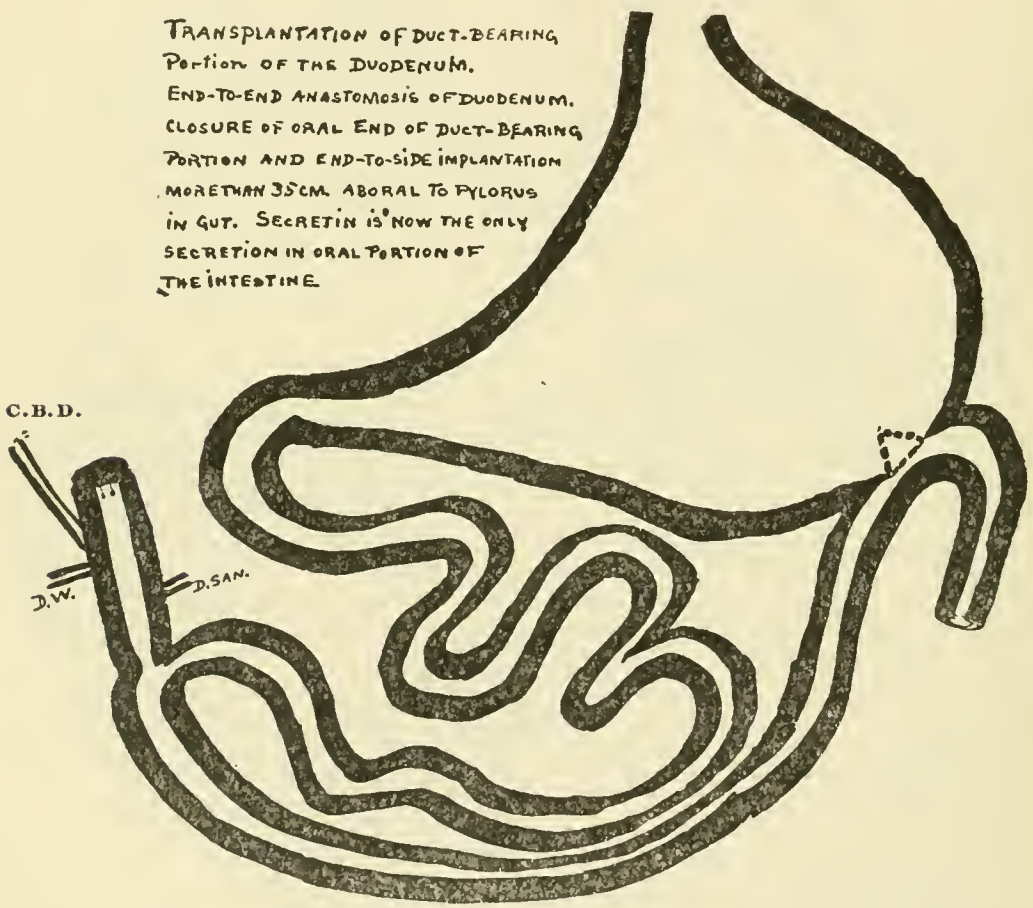


as to connect the loop with the stomach failed to be instrumental in preventing death. Drainage of the loop into the stomach is therefore shown to be without effect in preventing death.

Having eliminated nervous shock, as the source of lethal

impulse, as well as poisoning from food decomposition, obviously it became evident that the cause of death might lie in the production of poisonous substances produced by a mixture of the biliary and pancreatic secretions. It seemed possible, moreover, that this hypothesis might give us the real explanation of the fact that 35 centimeters or more of intestine in the closed duct-bearing portion sufficed to avert fatal results. For we may conceive that in this length of intestine such a quantity

FIG. 6.


TRANSPLANTATION OF DUCT-BEARING PORTION OF THE DUODENUM.
END-TO-END ANASTOMOSIS OF DUODENUM.
CLOSURE OF ORAL END OF DUCT-BEARING PORTION AND END-TO-SIDE IMPLANTATION MORE THAN 35 CM. ABORAL TO PYLORUS IN GUT. SECRETIN IS NOW THE ONLY SECRETION IN ORAL PORTION OF THE INTESTINE.
C.B.D.
D.W.
D.SAN.

of diluting material may constantly be furnished as would be adequate to render harmless the mixture alluded to. This supposition seems to be corroborated by the recent discovery of Flexner that the biliary salts, unless in colloidal suspension, act as violent poisons. He states (Jour. Exper. Med., 1896, p. 174) that the conclusion may be drawn that the suspension of bile in a bland mixture of high colloidal strength protects

the pancreas from the immediate and acutely injurious action of the biliary salts."

Further, on page 167, he continues: "Bile contains two sets of constituents of highly different chemical composition crystalline principals and colloids. The biliary salts are known to act injuriously upon the cells while no direct cellucidal property is known either for the biliary coloring matter or the mucin."

None the less convincing as to the toxicity of the bile are the studies of Meltzer and Salant. They state: (Jour. Exper. Med., 1906, 8, p. 159) "We have positive and direct proof that normal bile from many rabbits possesses an exciting element capable of producing chronic convulsions in frogs." Page 165, "that contrary to the prevailing opinion, bile contains a tetanic element or an agent which causes increase of excitability of the nervous system. That stagnant bile as in the gall bladder, etc., invariably produces coma and paralysis, that the depressive and exciting elements of the bile are mutual antagonists; that the depressive element when present in a highly effective dose is by far the stronger of the two, while on the other hand the tetanic element becomes effective apparently in a dose far below that which constitutes the minimum for the depressive element. That bile salts seem to contain the tetanic element in an extremely less amount than the whole bile."

Moreover and also in support of the supposition that a true auto intoxication from biliary or pancreatic products is responsible for death in high intestinal obstruction, we quote from *Opie* (Diseases of the Pancreas). He showed by a long series of experiments that the introduction of bile into the pancreas caused either death of the animal within twenty-four hours or widespread destruction of the gland depending upon the amount of bile injected.

As a means of further study of this question, Dr. Blake suggested the possibility of transplanting the duct-bearing portion of the duodenum into the intestine at varying distances from the stomach. This is accomplished by means of section between the bile duct and the pylorus of the first portion of the

duodenum and a second section of the duodenum aboral to the entrance of the duct of Wirsung. The segment of gut thus removed is carefully sponged out and wrapped in hot cloths. The ends of the pylorus and duodenum are then united by end to end suture. More than 35 centimeters aboral to the pylorus an end to side implantation of the segment is done, the oral end beside the bile duct having been carefully invaginated. This is a difficult operation, but it can be brought to successful issue. Dogs emaciate quite rapidly after it has been done, so that the most recent operations practised have included a section of the intestine just aboral to the implantation of the duct bearing segment, and a gastroenterostomy by means of the triangular stitch between the stomach and the gut aboral to the section. This, it will be noticed by consulting the figure, produces the same results from an operative standpoint as is shown in Fig. 1, except that the loop of intestine from the bile duct to the pylorus is more than 35 centimeters in one case, while in Fig. 1, it is not more than 10 or 12 centimeters. These experiments are not as yet concluded.

A simpler method of testing the effect of the presence of the secretions would naturally be to tie the pancreatic ducts and the bile duct. This is easier from a technical standpoint, but of course it does not produce conditions in any way resembling the normal as does the transplantation technic already referred to. Nevertheless in a number of experiments, both the ducts of Santorini and of Wirsung have been tied as well as the bile duct. This series is not yet far enough advanced to enable us to make a report upon it. Some of the dogs have died and on autopsy the pancreas has been found to be exceedingly hard, while the omentum has been dotted with unmistakable areas of fat necrosis. This gross evidence of pancreatic lesion has not been observed in our cases of pseudotetanic death occurring after duodenal section and infolding just aboral to the ducts. It suggests therefore that the form of death in the one case may have been different from that in the other.

In another series of experiments, the bile duct alone has

FIG. 7.

Photograph of specimen obtained from a dog in which acute duodenal obstruction was established. Cholecystenterostomy and twine triangular gastro-enterostomy and section of common duct were done at same time. Pancreatic ducts intact. Dog appears to have lived because of transplantation of the bile from duodenum into ilium. 1, Duodenal pouch. 2, Infolded aboral end. 3, Pancreas. 4, Site of stoma. 5, Cholecystenterostomy. 6, Cut end of common duct. 7, Cecum. 8. Remnants of liver. Mounted by Dr. Brown.

been tied with two ligatures and divided between them. Here again the series is as yet too short to enable us to make any positive statements, but several dogs in which the bile ducts were cut, have lived with a short duodenal pouch and twine triangular stoma.

A method for transplanting the point of bile entrance beyond the 35 cm. line and one less difficult as well as less apt to be accompanied by adventitious pathological conditions such as fat necrosis is a simple chole cystenterostomy. This has the added advantage of separating the bile and pancreatic secretion. It is not easy to do this operation in two steps because of the formation of troublesome adhesions and done at one sitting, prolonged as it must be by gut section and infolding and by the triangular enterostomy, there is danger of death from shock or later by peritonitis from leakage. We have done two of these one-stage operations without a death by shock, but followed by fatal peritonitis on the fourth day. The third dog lived three weeks, and was killed to obtain the specimen shown in Fig. 7. It is immaterial that the animals died of peritonitis—the point of interest is that they survived beyond the time which would have been possible had the bile been passing down its normal channel.

MacCallum of Johns Hopkins who, with associates, has given us a most elaborate and exact study on ileus inclines to the belief that death is due to the absorption of bacterial toxines, which enter through the impaired gut wall. Clinically Mayo and others have confirmed this assumption by observing a lowered mortality to follow a wide resection of the dilated gut. Nevertheless it seems noteworthy, first, that total exclusions of gut segments may be made which, left in the abdominal cavity gradually grow to great size (see paper of Blake & Brown in this issue) without producing any signs of toxemia; second, that this work has been done in the relatively germ-free portion of the gut; third, that obstruction is tolerated during the cutting out of the control if placed oral to the bile duct while it always is fatal before the control cuts out, if situated aboral to it.

In conclusion it may be said that so far as our experiments go, there seems reasonable ground to believe that they demonstrate that death in duodeno-jejunal obstruction may be due to the absorption of toxic elements in the bile which are normally rendered harmless by dilution and colloidal suspension in the secretions of the small intestine. That as the length of small intestine from the bile duct to the site of obstruction decreases, so the diluting secretions decrease and the toxicity rises proportionately. That if further experimentation definitely proves that bile is directly the cause of death in certain forms of intestinal obstruction, it may be possible to lower the operative mortality. For a knowledge of the pathology of a condition is the first step toward the establishment of a successful mode of treatment.

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STUDIES UPON THE FUNCTION OF THE PYLORUS AND STOMA AFTER GASTROENTEROSTOMY HAS BEEN PERFORMED.

BY NOEL BLEECKER LEGGETT, M.D.,
AND
J. W. DRAPER MAURY, M. D.,
OF NEW YORK.

A GREAT deal of speculation has been indulged in as to the physiological conditions which exist after the operation of gastroenterostomy. Undoubtedly the most important and thoroughly scientific and accurate observations were made by Cannon in his recent studies at the Harvard Medical School. Together with Murphy, he performed the operation of gastroenterostomy on a large number of cats, and after full post operative recovery, studied the animals' intestinal mechanism through the agency of the fluoroscope. He found according to these observations that all food was driven by the muscular contractions of the stomach through the pylorus, the stoma playing no practical part in alimentation. This was a profoundly important contribution.

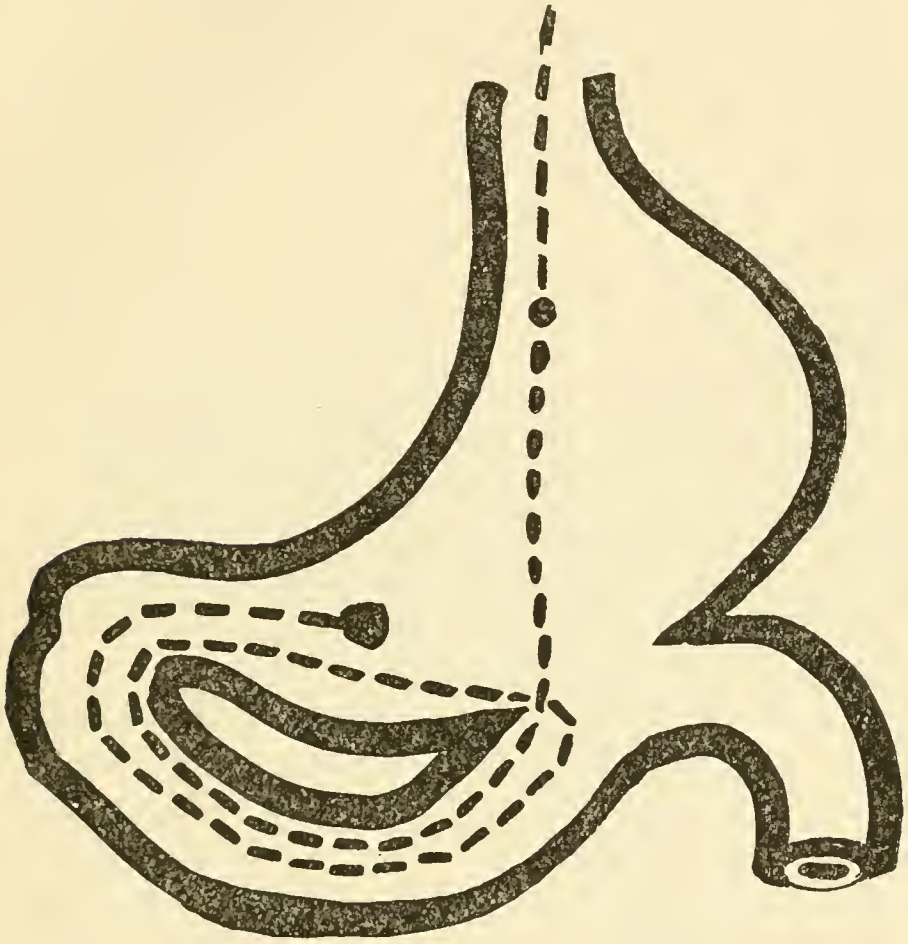
About a year ago, the class in operative surgery at the Surgical Research Laboratory at Columbia University performed the operation of gastroenterostomy. We were making some observations upon the efficacy of various forms of superficial dressings, and in this particular case, a certain dressing was applied upon a small piece of gauze. While not under observation, the animal picked out the smaller dressing from under the external bandage and swallowed it. Some time after this, he was chloroformed for the purposes of study, and upon opening his stomach, the gauze was found trailing through the stoma. We were immediately interested in this, because Cannon's observations had just been published. Unfortunately no record was made as to the direction taken by the tip of the gauze which had passed through the stoma. This is unfor-

tunate, because later observations suggest that solid bodies, which pass through the stoma, may all travel toward the pylorus.

During the past winter we determined to study this interesting problem of pyloric and stoma function and decided to investigate it from three standpoints, viz. (1) By studying the course taken by solid particles which were tied to a string. (2) By feeding fat and studying the condition of the lacteals an hour later. (3) By performing gastro-colostomy or gastro-ileostomy near to the valve and making observations upon the weight of the animal. For the feeding of string, no originality can be claimed, it having been used for many purposes notably by Abbe and Dunham. The particular purpose to which we have put it, however, we believe to be original. We conceived the idea that if gastroenterostomy were done and time allowed to elapse for the perfection of healing and for the establishment of any new physiological functions to which origin might be given by the operation, it would be fair to assume that solid food particles ordinarily passed on and digested, would take the same course as indigestible solid particles tied to string. The dogs accordingly underwent gastro-duodenostomy or gastro-jejunostomy, as the case might be, the technic being that of open incision and suture. Not less than two weeks later, they were permitted to swallow a piece of meat in which a small bullet, tied securely to the end of a piece of string, was embedded. A dog lends himself favorably to this manœuvre, because of his natural voracity. In an instant the meat, bullet and one end of the string are in his stomach. The next part of the procedure consists in anæsthetizing the animal to very profound narcosis. On separating the jaw very widely the pterygomaxillary ligament is brought clearly into view. The string being threaded on a short curved round needle is quickly passed through the ligament and tied. This should be done loosely so as not to cut through. Another point in the technic is that the string should not be tied to the meat: it being preferable probably to wrap it once or twice tightly around it.

The pterygo-maxillary ligament is situated so far aboral to the teeth that the animal does not bite the string off, and it remains hanging down the œsophagus. Its situation is so far

FIG. I.



LINE DRAWING OF A SPECIMEN OBTAINED BY PERMITTING A DOG TO SWALLOW A PIECE OF STRING. BAG OF SHOT TIED TO END PASSED THROUGH THE STOMA, DUODENUM AND PYLORUS TWICE THE SAME FORCES MAY CARRY MURPHY BUTTONS FROM THE GUT INTO THE STOMACH.

STRING TIED IN PHARYNX TO PTERYGO-MAXILLARY LIGAMENT.

back in the pharynx that the string will remain for days in this position without creating any choking or discomfort of any kind whatsoever.

It is difficult to get the string to pass out of the stomach. If it is too long, it simply rolls up and lies in the stomach

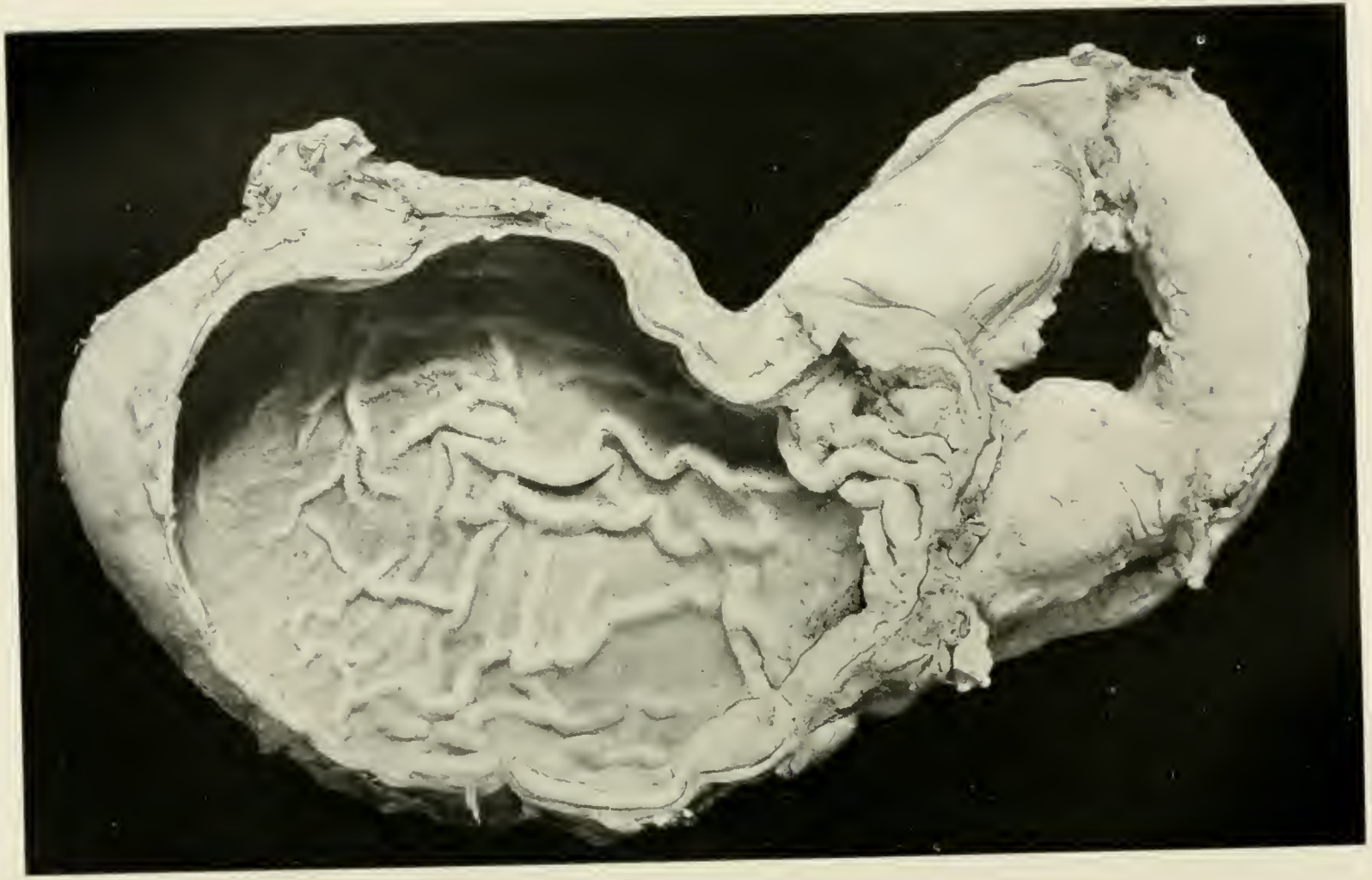
imbedded in a mass of mucus and food. If too short, it will obviously not have the requisite length to give a demonstration of the facts under investigation. We are fortunate in having secured a specimen which Dr. Brown has mounted very beautifully, and of which both a photograph and a line drawing are shown in the illustrations Figs. I and II; it will be seen that the bag of shot passed directly into the stoma and instead of travelling aboral, it proceeded oral, Fig. II, toward the pylorus through it and into the stomach. Following the trail of string which it left behind, it can again be traced over exactly the same ground. This study appears to prove that at least under certain conditions and at certain times solid materials do pass through the stoma even when the pylorus is left untouched and it is in normal condition. This is further suggested by Fig. III, which shows a piece of *bone* lodged in the stoma. The results of further string feeding are shown in Fig. IV. This string passed direct through the pylorus. Thus some strings pass one way and some the other way. Figs. V and VI illustrate the same point.

Pyloro Stoma Function as Demonstrated by the Lymphatics.—We are fortunate in being able to report one case which lent itself very favorably to this demonstration. We had fed the dog string, and it had worn the string for the usual period of about 24 to 48 hours, when we determined to feed it fat prior to chloroforming it. About one hour after the fat meal, the animal was opened under profound anæsthesia. The gastro-ileostomy had been situated near to the ilio cecal valve, as shown in Fig. VII. By good fortune the mass of meat in which the string with its shot had been imbedded proved to be of a very indigestible type, and it was discovered considerably macerated but still in statu-quo lodged in the ileum about 20 centimeters oral to the stoma. The lymphatics of the duodenum from the very beginning of the mid gut, viz., some four to five centimeters aboral to the pylorus, were loaded and distended with emulsion. This, parenthetically, affords a convenient means of observing the similarity in function of the stomach and first portion of the duodenum from which no

FIG. II.

Photograph of specimen from which Fig. 1 was made.

FIG. III.



Studies in the Functions of the Pylorus.

FIG. IV.

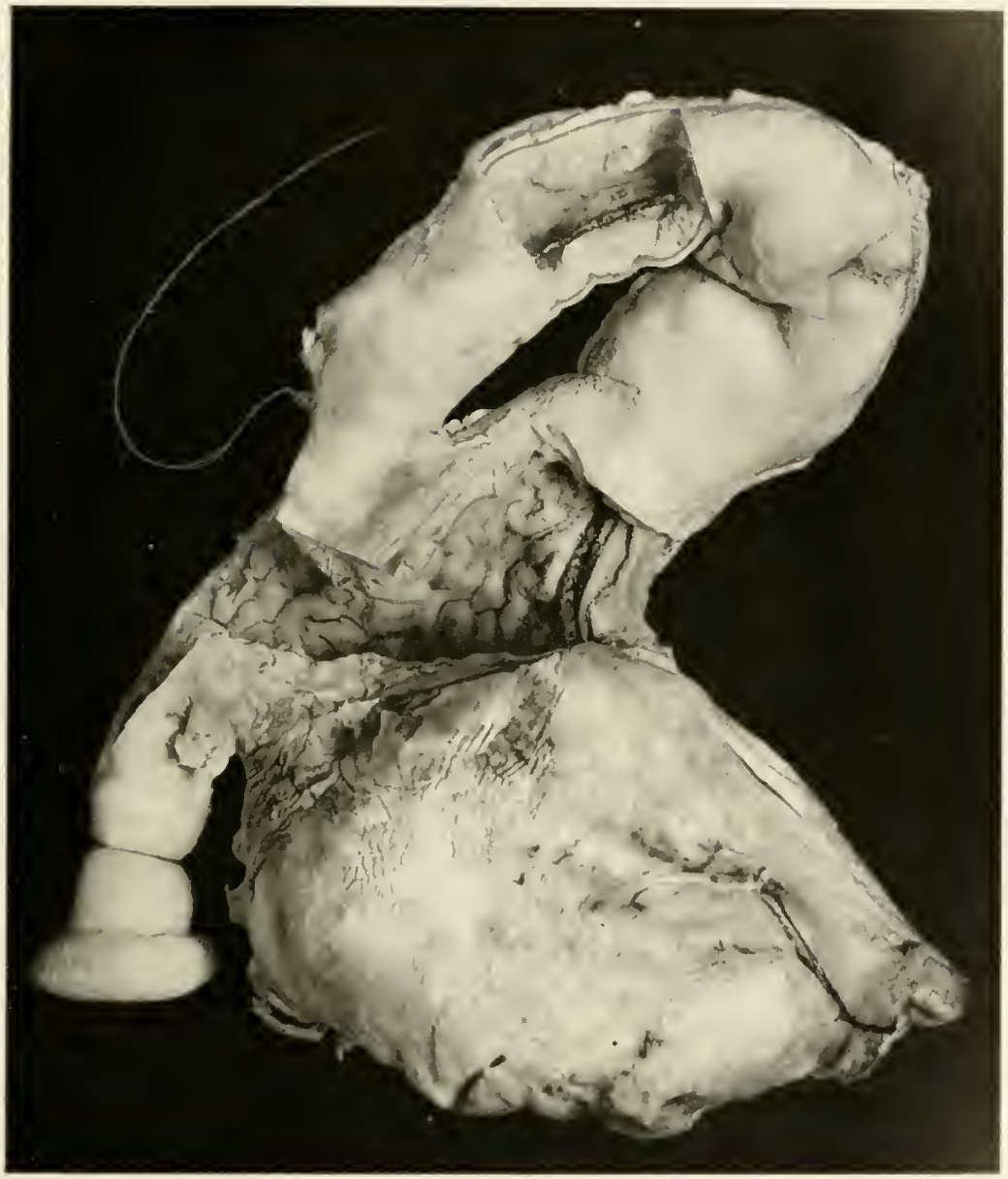
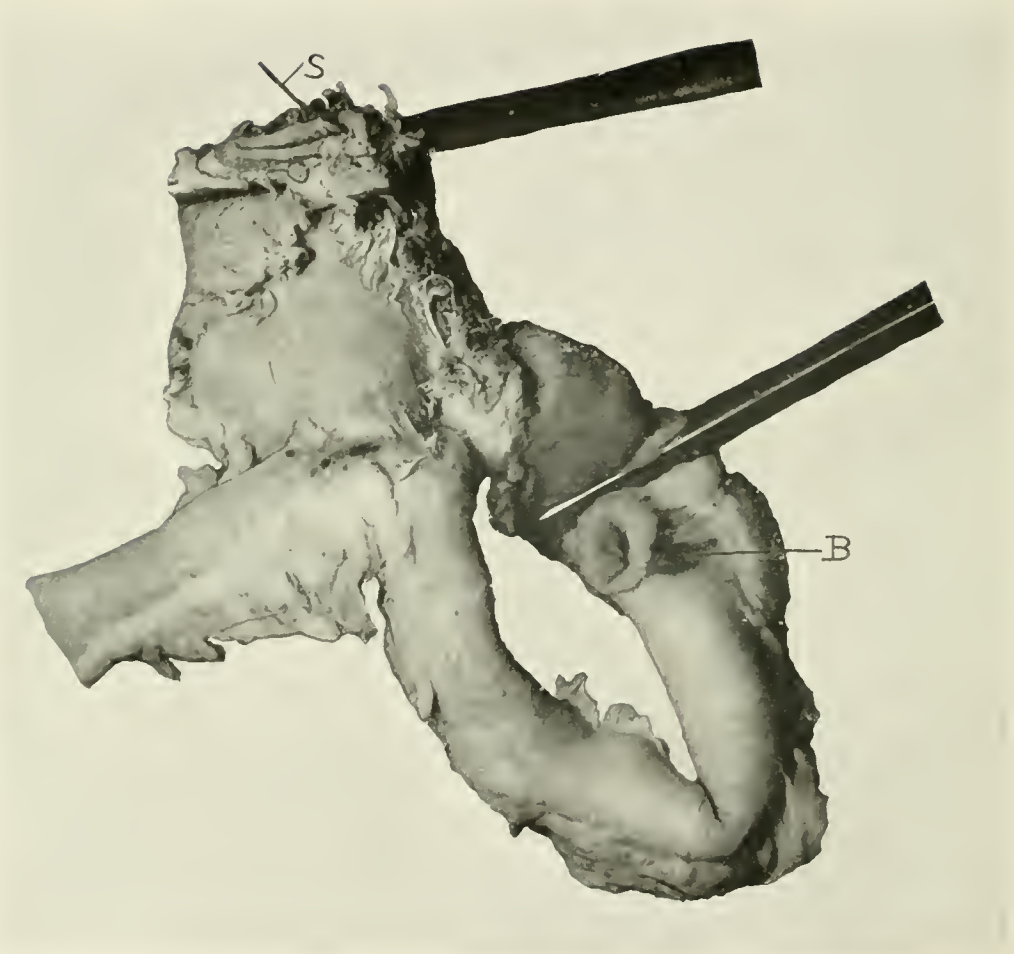
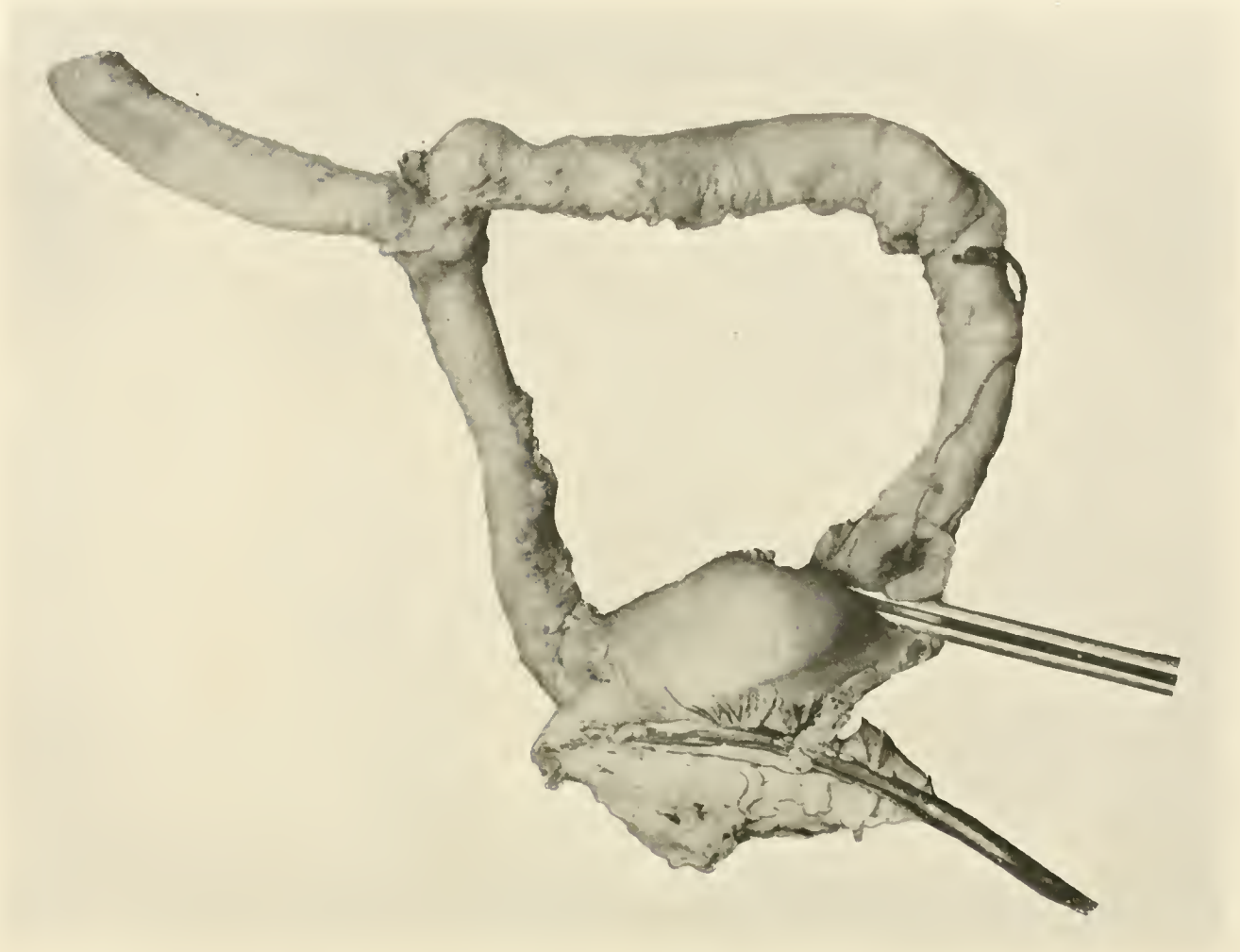


FIG. V.



Photograph of specimen of gastro jejunostomy after string had been fed. The clamps were applied before specimen was removed so as to be certain that string was held in primary position. Note string at S; œsophagus and bullet on aboral end at B, where duodenum was cut.

FIG. VI.



Y gastro-enterostomy. Clamps applied as in Fig. V. Opening shows string which, with bullet, had passed through pylorus. This is suggestive for stoma drainage and was very perfect owing to end to side implantation of gut at stoma.

absorption whatsoever seemed to be taking place, two structures morphologically very dissimilar, but shown functionally to have a common origin in the primitive foregut.

FIG. VII.

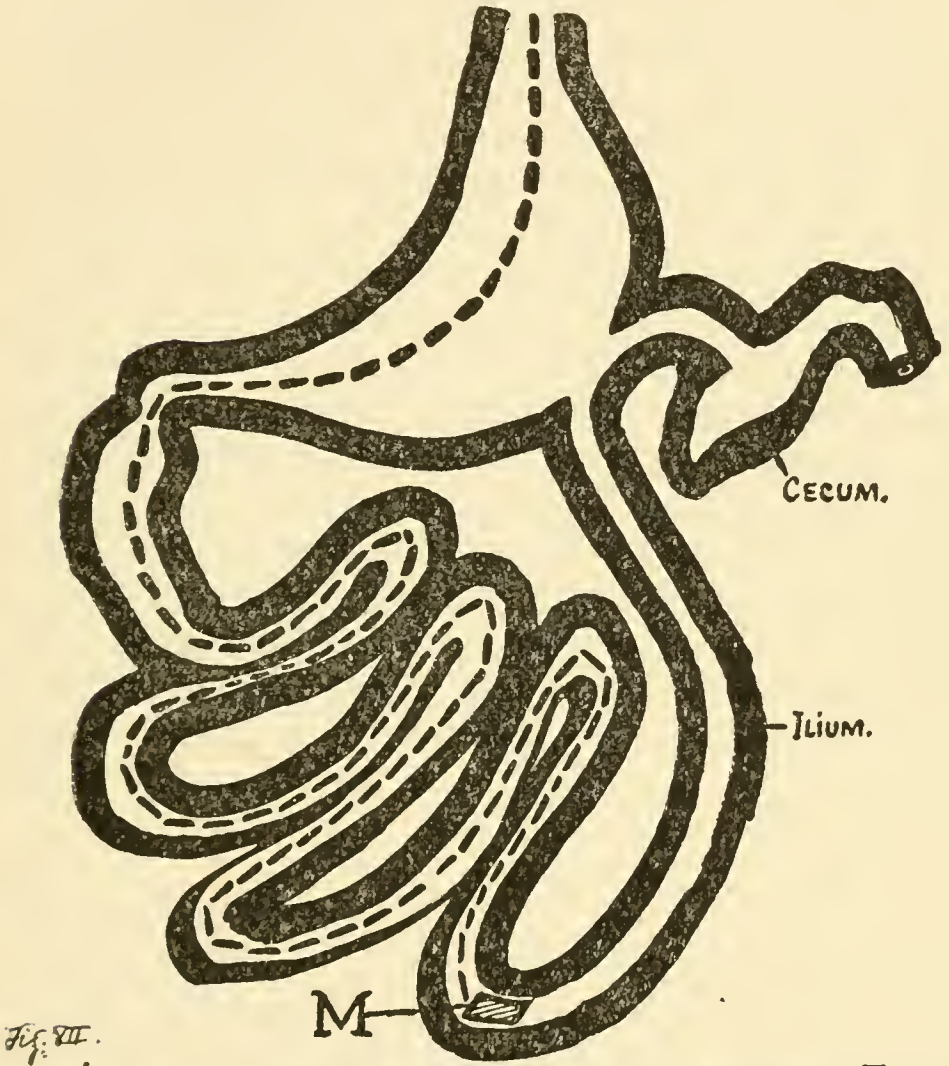


Fig. VII.

THIS DOG SWALLOWED MEAT WITH STRING ATTACHED. TWO DAYS LATER WAS FED FAT. KILLED ONE HOUR LATER. LYMPHATICS ORAL TO POINT M, WHERE MEAT LODGED IN GUT, WERE GORGED. THOSE ABORAL TO M WERE EMPTY. PROVES THAT FATS DO NOT PASS THROUGH STOMA.

The lymphatics of the entire intestine from the second portion of the duodenum down were well filled. This lymphatic congestion terminated abruptly opposite the piece of meat which was lodged in the ileum and held there in place by

the string. On the aboral side, viz., for a distance of about 20 centimeters between the lodged meat and the stoma, it was positively demonstrated that no absorption whatsoever was taking place. Aboral to the stoma there was also no lymphatic engorgement. In this particular case, it therefore seemed that probably no fat had passed through the stoma; that all had gone through the pylorus. This, of course, presupposed that pancreatic secretion had passed beyond the meat.

These two studies are suggestive and are to be followed by more of a similar nature which are in course of preparation at the laboratory. It may well be that some slight variation in the technic as to length of loop, direction of incision in the stomach wall, position on anterior or posterior wall, mode of attachment of intestine to stomach and other even less significant factors may play parts at present entirely unknown in determining the function of the stoma in the presence of an unobstructed and natural pylorus. It has been thought (Mayo and others) that the stoma should be made at the most dependent portion of the stomach in order to functionate. This can be readily understood to be of great importance in the presence of atonic dilatation and pyloric obstruction. Our experiments, as yet incomplete, seem so far to show that the position of the stoma makes no difference in its function, at least we have not as yet been able to determine that it does.

Observations on Stoma Function by Recording the Weight of the Animal.—If a gastro-ileostomy be done very near the valve or if one goes so far as to perform gastro-colestomy, a study of the weight of the animal after this operation cannot fail to throw some interesting light upon the function of the stoma. Moreover observations on the feces are also not without importance, because if passed directly through the stoma, they would not have undergone digestive processes. Graphic charts of the weights of our animals have not yet been made, neither have the feces been examined microscopically or chemically. Gross examination however has as yet failed to show any difference in the feces of dogs operated on in this manner from those of unoperated dogs, and our observations

on weight appear to show that for a time after operation the dogs, usually thin and in rather poor condition, having been half starved on the streets, frequently gain in weight for about a week. They are then apt to lose weight rapidly for a week, and even though fed carefully with milk and dog biscuits, are prone to die at the end of the second or third week from inanition. Autopsy findings rather constantly show the long loop to be somewhat dilated and filled with soft grumous material. Pretty well marked spur formation at the side of the stoma has been a constant feature in these cases. Further study alone by means of feeding string and fat by the technic and at the times herebefore described will alone answer the question why these dogs should at first gain, then lose weight and why inanition and exitus should subvene so rapidly. It is not improbable that the profound nutritional changes that certainly do accompany many of these stoma experiments are due (Turck) to interference with normal colon bacillus action or to the establishment of chemical reaction unfavorable to digestion. In any event the experiments support Blake's contention that gastroenterostomy should not be done except in the presence of pyloric stenosis.

Reprint from Surgery, Gynecology and Obstetrics, May, 1906.

COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY, NEW YORK

Department of Surgery

WHAT BECOMES OF LEMBERT STITCHES PLACED IN THE GUT?[1]

By CARL EGGERS, M. D., and J. W. DRAPER MAURY, M. D.

STUDENTS very frequently ask why non-absorbable material is placed in the gut while absorbable sutures are by very general consent now advised for every other tissue in the body except the skin. Believing that an answer to this question would be of interest to students, and to practising surgeons as well, particularly those whose environment does not permit of their carrying on research work, we thought that a brief report on some of the gastrointestinal preparations recently made at the laboratory which had a bearing on this subject would be of interest.

There are obviously three possibilities: 1. The Lembert stitches may remain in situ indefinitely. 2. They may be in part intruded into the gut. 3. They may be entirely intruded into the gut, and with its contents be swept to the outside. Examples of each of these three conditions have been seen at the laboratory, but before discussing them, a statement should be made as to how the specimens were prepared.

During the last two years, a large number of preparations of gastroenterostomy and enteroenterostomy stomata have been made in dogs with the twine triangular stitch. This technique, described in the *Annals of Surgery*, June, 1905, affords an unusually good opportunity to study the fate of the Lembert stitches, since no through-and-through stitches whatsoever are made. It may be remembered that the technique consists simply in casting a Lembert stitch about a twine, which has been so inserted as to punch out triangular pieces of the included viscera. The illustrations herewith presented are from drawings made by Mr. Peterson, artist to the anatomical department of the university. It will be seen that the thread which in every case was inserted by continuous suture is intruded in greater or less degree into the lumen of the gut.

It is obvious that the drawings are concerned with the second possibility above mentioned; viz., with those cases in which the stitch is partly intruded into the lumen of the gut.

Some of the specimens taken from animals which had survived operation as long as three months do not show this intrusion, and the Lembert stitch, which was made with black thread, is plainly visible imbedded in the tissues. Intrusion, therefore, in a considerable portion of the cases, if it occurs at all, does not take place until after the fourth month. We have noticed that it is only in those cases where there was a short post-operative life that the stitches are to be found hanging in the lumen of the gut. Specimens taken from animals with long post-operative lives showed either an absence of the stitch or its deep imbedding under the serosa..

Fig. 1.

[1] From the Surgical Research Laboratory

Of a series of eighteen cases examined, six showed intrusion of the stitch in various degrees. In all cases, the animals had had relatively short post-operative lives; viz., from a week to a month. Eight showed the

Fig. 2.

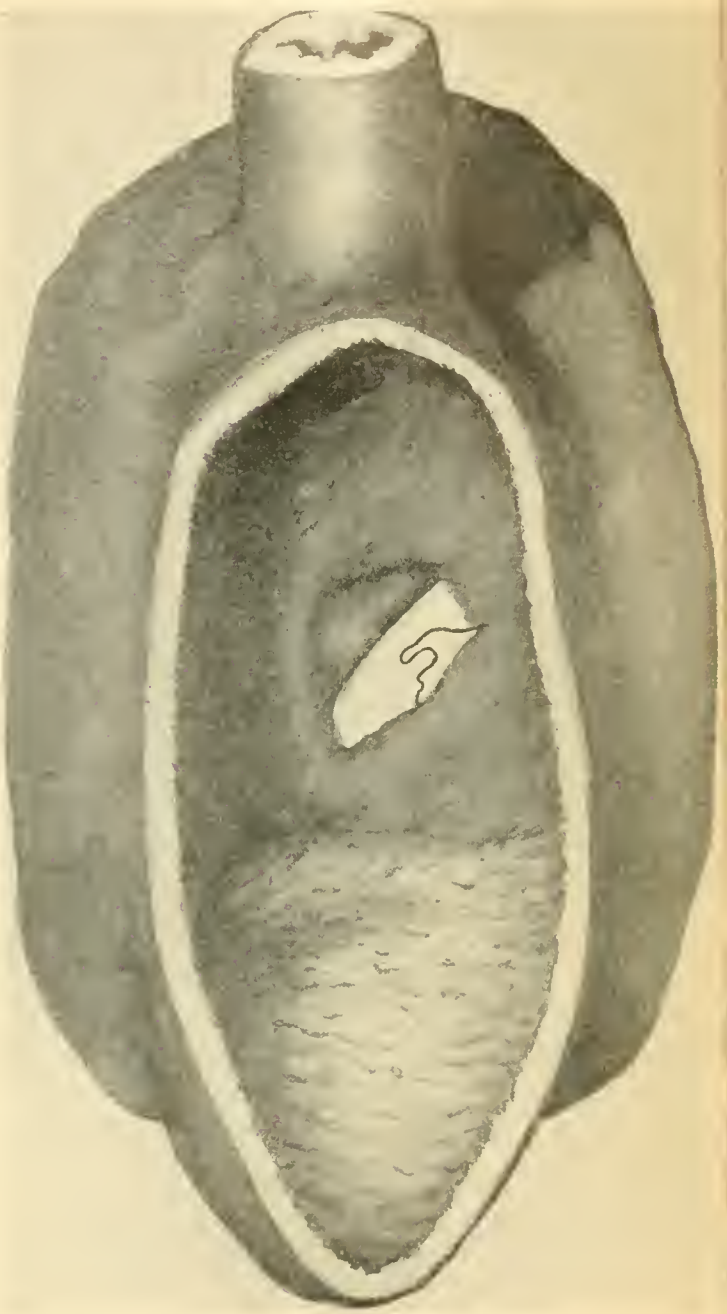


Fig. 3.

stitch to be imbedded; these, in general, had longer post-operative lives. In four, no sign of the stitch could be found.

Why some of these Lembert stitches should remain in situ and why others should disappear, presumably by intrusion into the lumen, we are at a loss to say. It is possible that the intrusion may be accounted for by the fact that the Lembert stitch, supposedly taken into the submucosa only, was accidentally carried too deep, and actually pierced the mucosa.

THE TWINE TRIANGULAR STITCH FOR GASTRO- AND ENTERO-ENTEROSTOMY.

BY J. W. DRAPER MAURY, M.D.,

OF NEW YORK

Instructor in Experimental Surgery, Columbia University.

In presenting this paper, I wish to state that the facts recorded in it represent the result of the work of a number of undergraduate students in the medical department of Columbia University. Mr. Donald Gordon built the animal cage; Messrs. Kussler and Thomas perfected the knot as it is used to-day; Mr. Charles K. Stillman has made the drawings for the illustrations. Mr. Eggers has taken charge of the laboratory, and has operated on many occasions with the assistance of less trained students. The results, then, represent a portion of the studies carried on by the under-graduate students of the Surgical Research Laboratory of Columbia.

The object of this paper is to present in full detail the method of application of the twine triangular ligature and to report the experimental and clinical status of the method.

Fig. 1 shows a diagrammatic outline of a conventionalized colon and mesocolon with the posterior wall of the stomach pushed down from above through the incised mesentery. After selecting the portion of the small gut which is to be united to the stomach, a point is chosen upon it about 90° from its mesentery, and, upon determining the portion of the gastric surface where the stoma is to be made, the gut and stomach may be held by an assistant, as shown in Fig. 2. We are indebted to Dr. Walter B. Cannon, of the Harvard Medical School, for this technical use of the word "stoma," he having first used it in describing his well-known observations on the motor activities of the stomach. The 90° distance from the mesentery is chosen for the line of insertion of the posterior row of continuous Lembert stitches so that when the triangular suture is finished and the anterior Lembert layer is closed

around it, about 180° of the circumference will have been used up in making the stoma. The remaining 180°, then, constitute a lumen through which food may without difficulty pass, pending the sloughing out of the stitch. In human beings, the length of this Lembert should probably in no case be less than ten centimetres. A few centimetres of this Lembert continuous stitch should be left, as shown on the slide, at the point of beginning, to serve as a guide in the completion of the stitch, and knots may be tied at intervals, if desired. It has

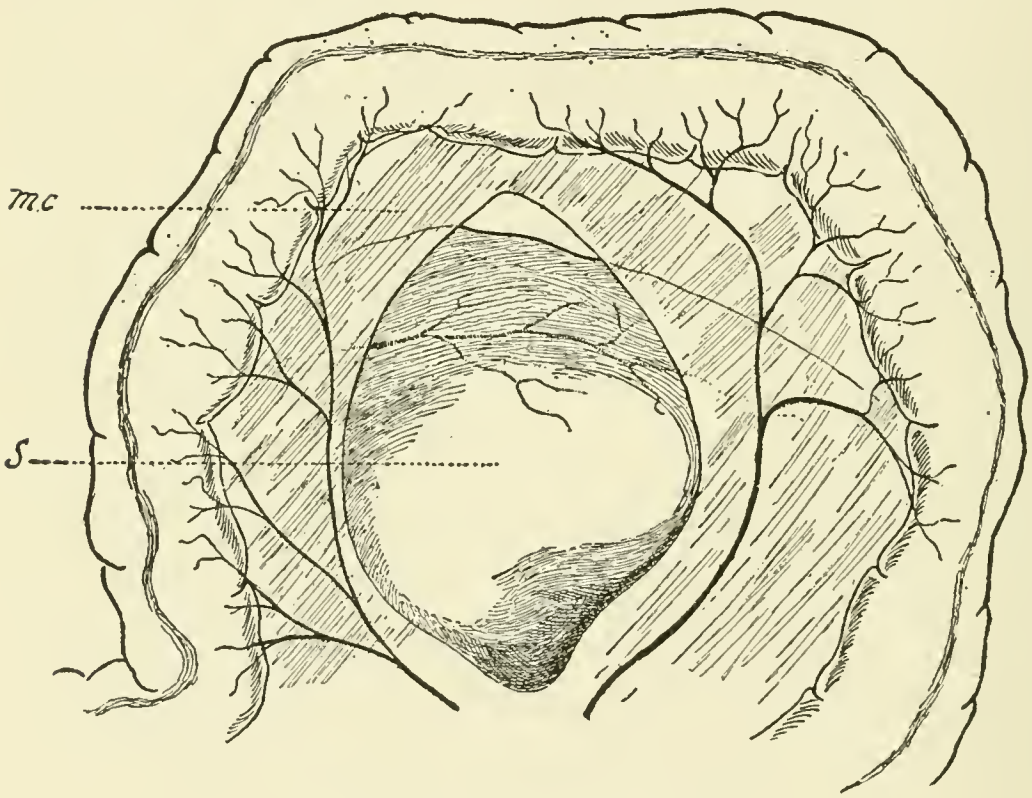


FIG. 1.—Exposure of posterior gastric wall.

been our custom at the Laboratory to tie the Lembert before beginning the insertion of the triangular stitch, but Dr. Abbe has shown that this is not necessary.

The next step in the technique, as shown in Fig. 3, is to insert the triangular ligature. The beginning and end of the Lembert serve as guides for the basic angles of the triangles. The needle, then, is thrust into either the gut or the stomach at the apex, which lies in the perpendicular erected at the centre of the base and less than a diameter of the gut distant from it, and is carried in either direction to one or other of the points

named. The ligature is shown as beginning in the stomach, *A*, near the vessels of the greater curvature. It then passes to *B* and emerges. The distance from *B* to the extremity of the Lembert should not be more than one-half centimetre. The needle enters at *C*, care being taken to pierce the mucous membrane, and the point is carried parallel to the Lembert to *D*, one-half centimetre from its termination. The needle is then

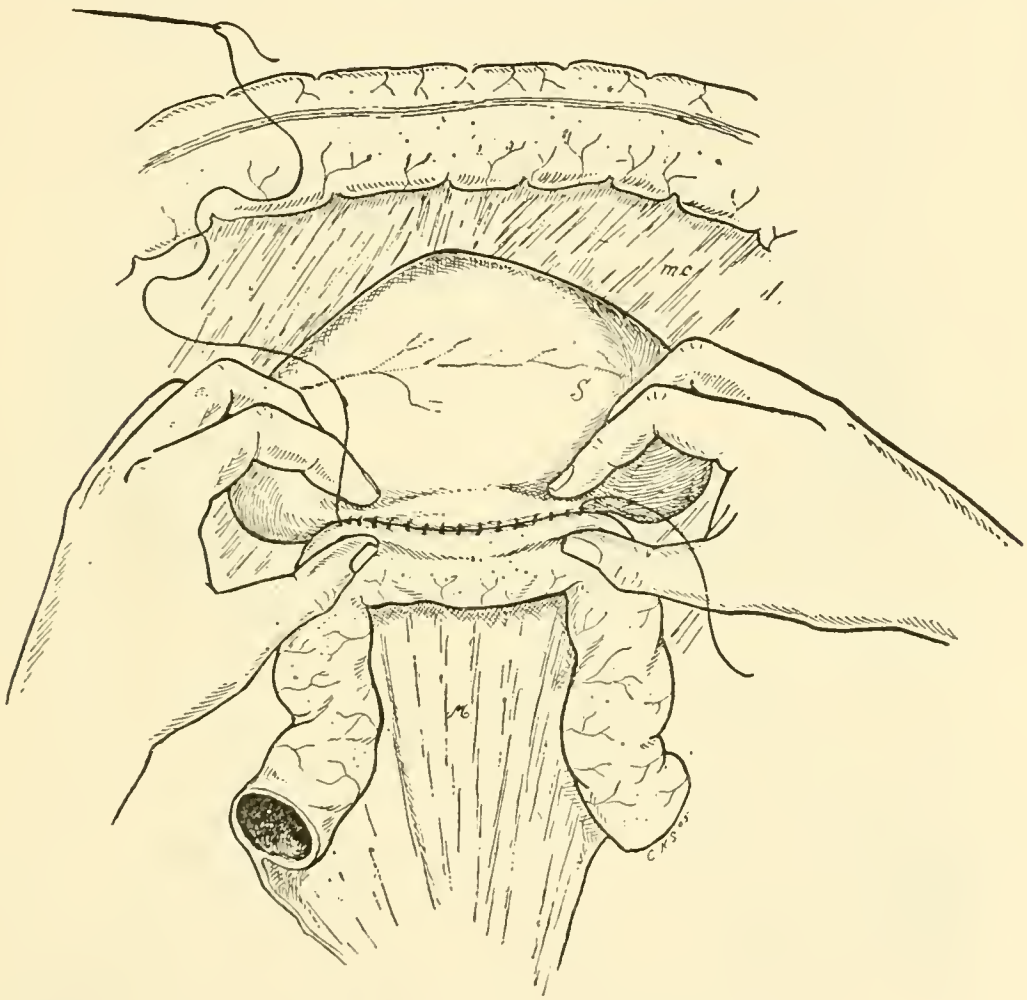


FIG. 2.—Insertion of posterior row of Lembert stitches.

plunged directly into the stomach at *E*, to emerge at the point of beginning. In this way the first triangle is completed.

Fig. 4 shows the appearance of the part after the insertion of the second triangle. Letters have here been omitted for the sake of clearness, but the arrows show the direction of the twine, and it is, of course, directly inverse to that taken in making the first triangle. It will be noted, as soon as the loop

is drawn down and the apices are approximated, that the entire stitch is out of sight within the lumen except at the angles of the triangle, where in each case it crosses twice.

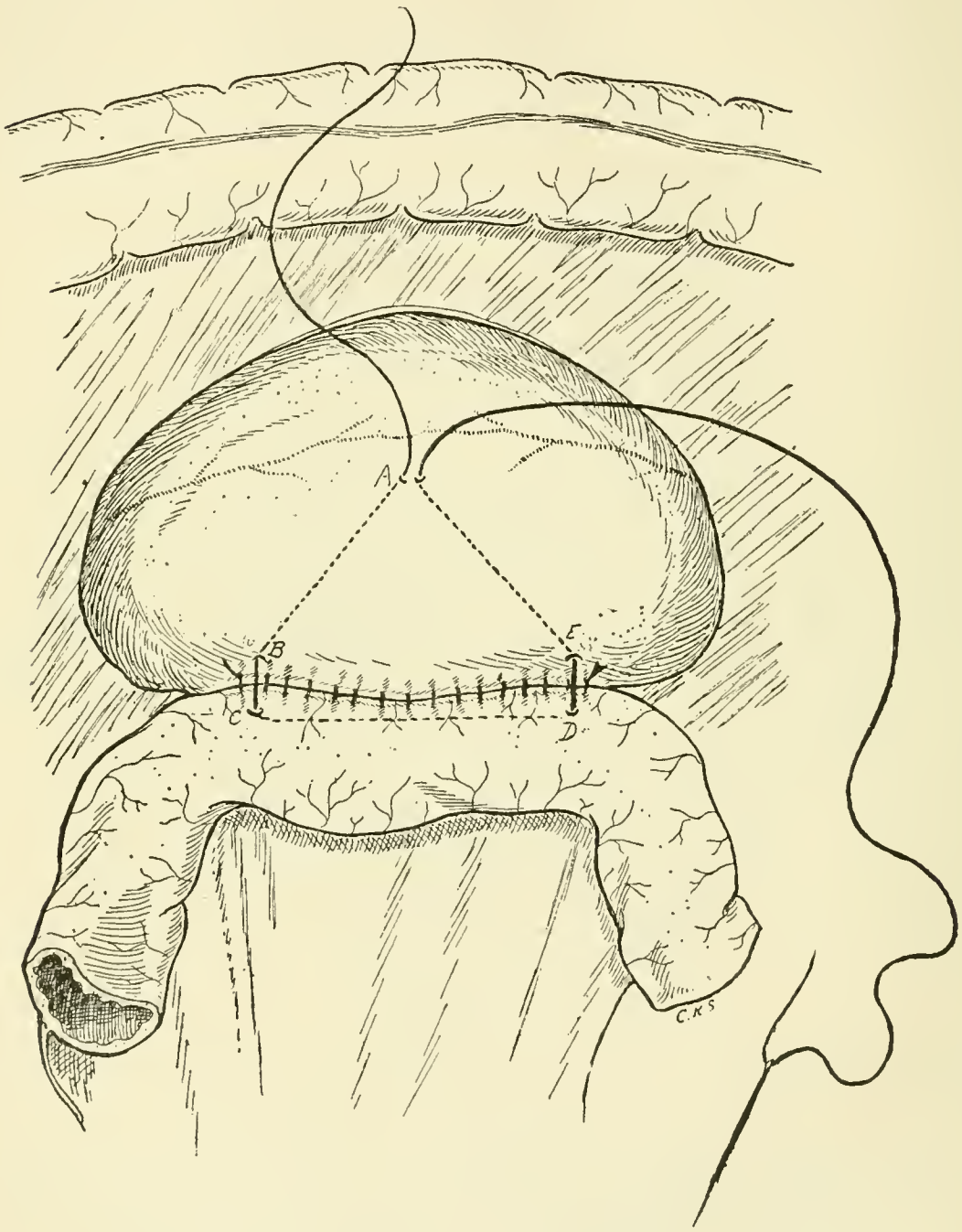


FIG. 3.—Insertion of the first triangle.

The stitch may seem complicated at first sight, but if the method be analyzed it will be found to be simple enough. That this assertion is well grounded is proved by the fact that none of the students have had the least difficulty in learning to insert

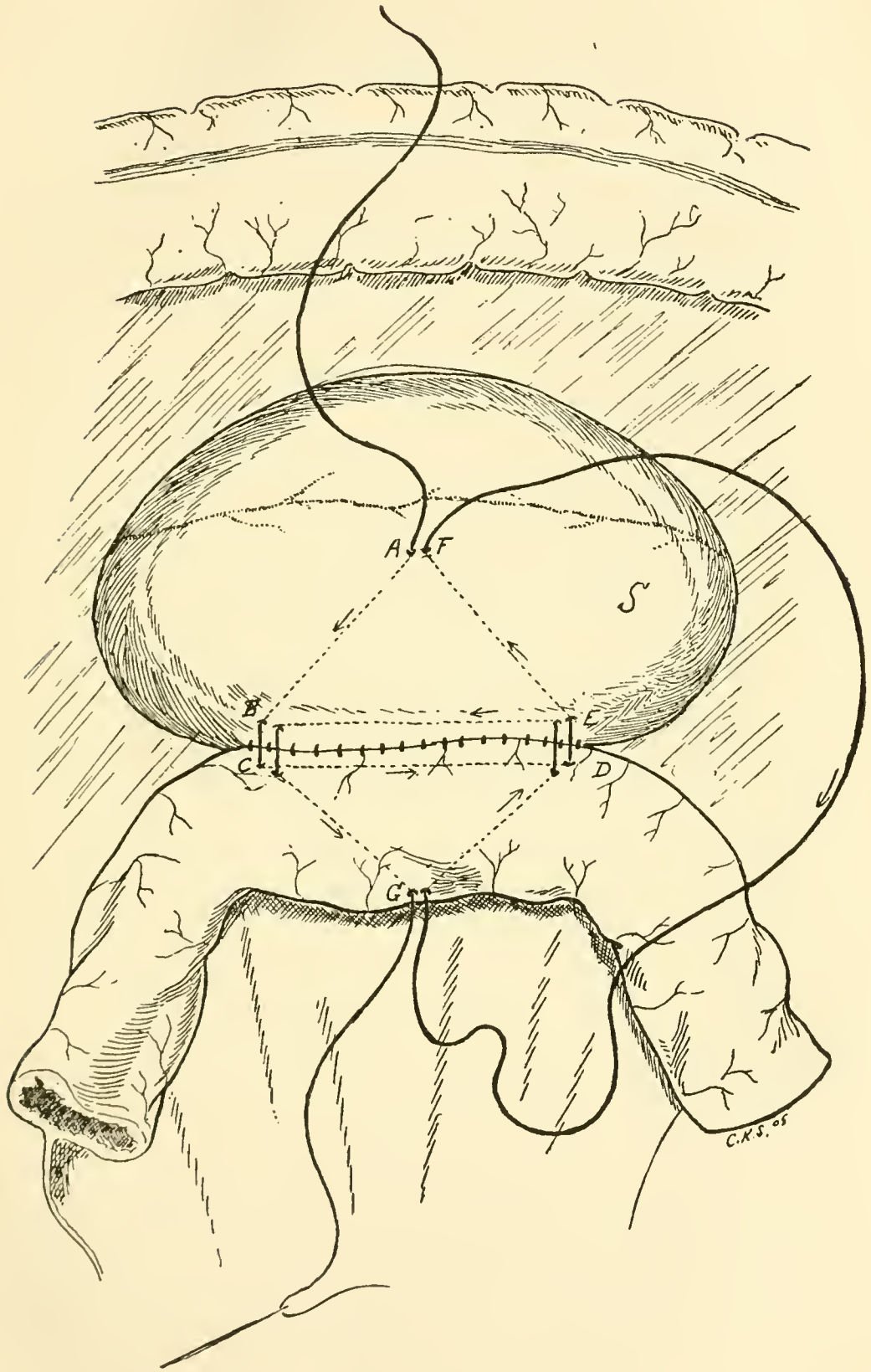


FIG. 4.—Insertion of the second triangle.

it. It should be remembered that the stitch consists simply of two isosceles or equilateral triangles superimposed. The apex of one is in the stomach, and its base lies beyond the Lembert stitch in the intestine. The apex of the other is in the intestine, and its base lies in the stomach beyond the continuous Lembert first mentioned. The length of the perpendicular of the intestinal triangle is easily determined by its relation to the

FIG. 5.—Approximating the apices.

diameter of the gut. It should be just a little less than equal to it, the difference allowing for the insertion of the Lembert stitches. This, in other words, disposes of the 180° of the circumference, which it has been found wise to allot to the stitch.

So far, it may be stated that the only point of importance in executing the technique, aside from following the direction

of the triangles as indicated, is that each time the needle is inserted it should be positively ascertained that it has pierced the mucous membrane of both viscera. This may readily be done by carrying it to one side or the other and gently feeling for the point through the wall of the viscus. The needle should not be too sharp; it should be round, straight, and about eight centimetres in length. It is convenient, although by no means necessary, while tying the first knot of the ligature, to press the row of Lembert stitches and the bases of the triangles downward. This juxtaposes the two triangular surfaces and raises them into a vertical plane. No effort should be made to tighten the ligature until after the first single knot has been made. It is further assuring to seize the twine at the two angles, just before the Lembert is folded down and the first knot in the twine is tied, with a pair of thumb forceps, and make sure by their freedom of motion that the needle has not, by any chance, transfixed the twine in any part of its varied course. This accident has happened once at the Laboratory.

Another technical point is that the twine of the second triangle should be brought out at the angles as nearly through the same needle holes as those caused by the insertion of the first triangle. A failure to do this probably caused the interesting condition seen in Fig. 11, where at *D* the twine triangular stitch is seen caught by a small bridge of tissue and having slung across it a hair ball, *C*, which had accumulated there in about two weeks' time as a result of the dog's having licked his wound. This is the only instance of the kind which has occurred at the Laboratory, but it is an interesting one, and suggests the importance of the details just suggested. If this rule be adhered to, such bridges of tissue cannot be left at the angles to hold the twine.

Fig. 6 represents a convenient mode of tightening the suture, and is the method usually employed at the Laboratory. As already emphasized, the experimental results amply justify the statement that a failure of the twine to cut through is ascribable to the failure of the operator to tie it tight enough, and not to any fault of the triangular ligature. Dr. John A. Bodine has graphically said, "I prefer this method to any

other because success depends entirely upon my own efforts, there being no faulty spring, as is always possible in the case of the Murphy button, or rotted ligature, as may be the case in the McGraw technique. If I get my brute strength down on the knot in that twine, I know those triangles have got to slough out."

Fig. 7 shows the Lembert completed and tied at the point of beginning, which, it will be remembered, was left long for this purpose. There is a distinct tendency, seen particularly when the technique is executed upon the gut of a dog, for the twine to cause a number of radiating folds which necessitate

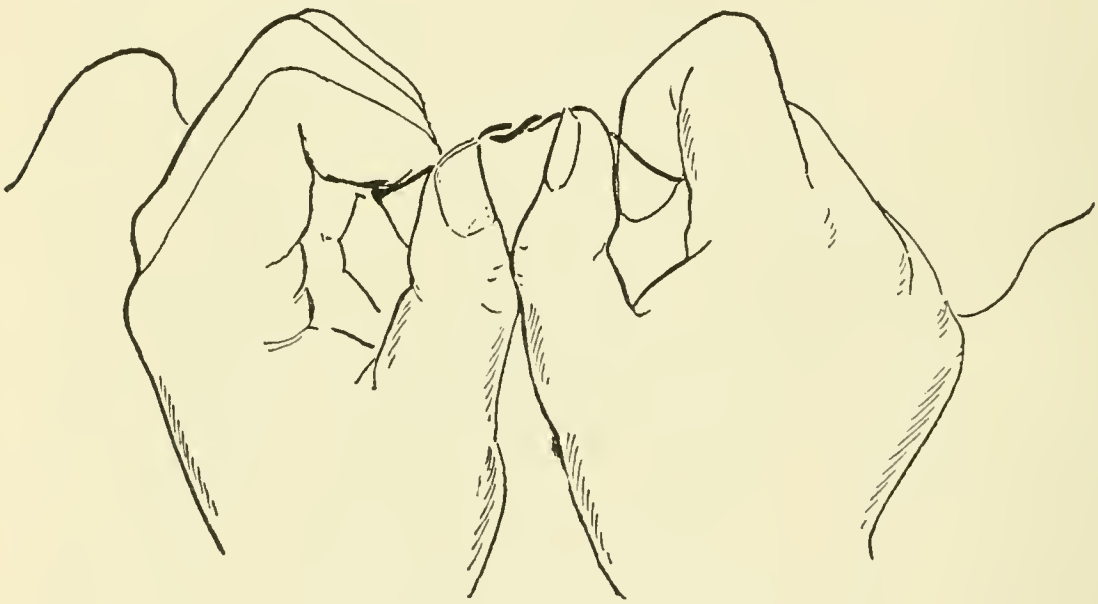


FIG. 6.—A method of making the knot absolutely tight.

a little care in the completion of the Lembert. In man they are much less marked, probably because the gut is more pliable, and also because it is of much greater diameter and much thinner. A point which we have usually tried to make in finishing the Lembert has been, so far as possible, to take the stitches at the bottom of these sulci. They are thus easily obliterated and give rise to no trouble.

This completes the description of the method of inserting the twine; and now I wish to turn to some of the experimental considerations which have been met with in the course of our work. It has been a moot point whether the twine would cut out as surely as does the McGraw elastic. After

careful experimentation with the two materials, it was found that in point of time as well as in certainty of operation they were identical.

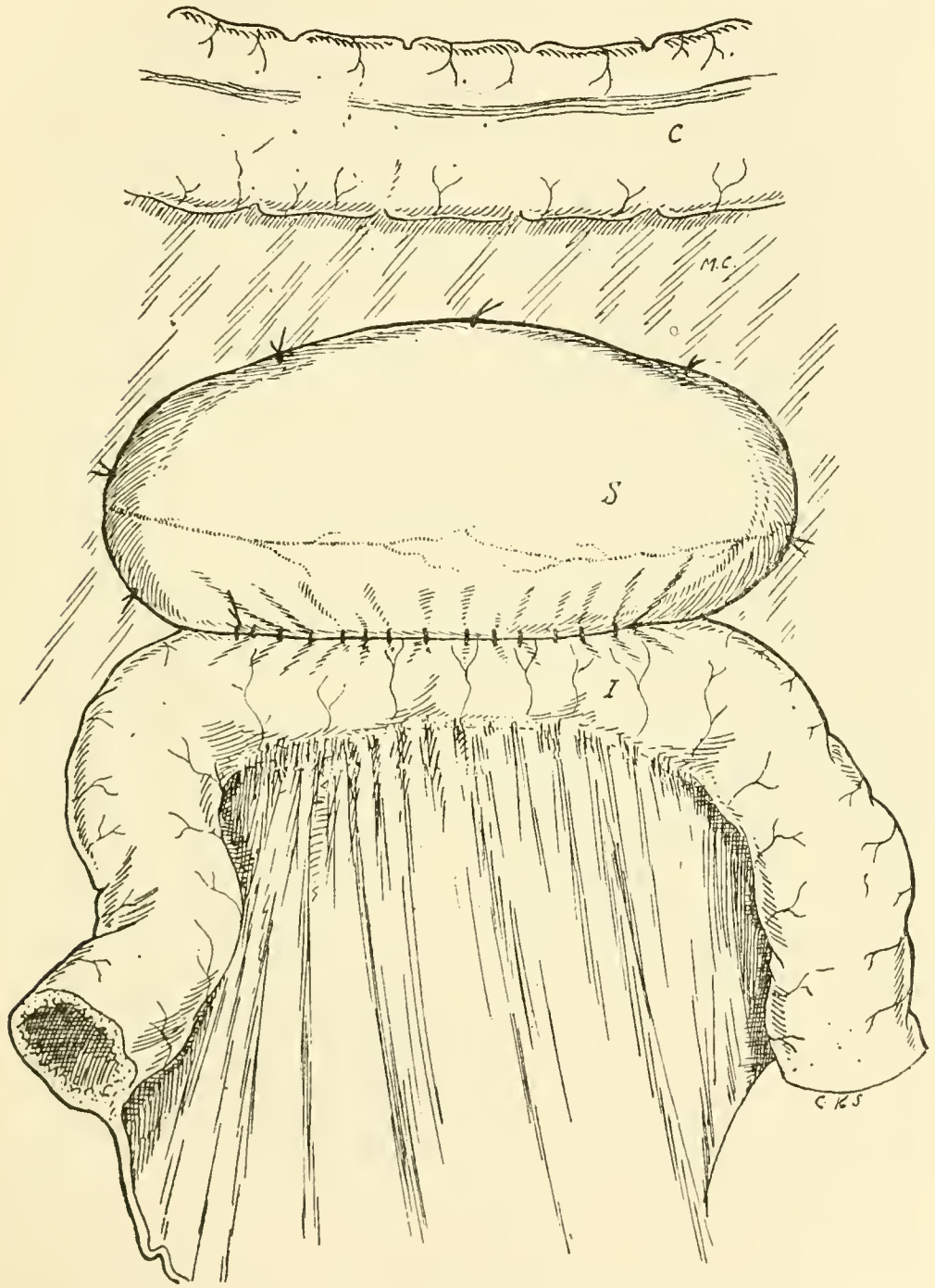


FIG. 7.—The anterior row of Lembert stitches has been completed.

Fig. 8 is a microphotgraph made from a section which was taken from dog No. 30. It shows the path of the twine triangular ligature after it had been *in situ* for about forty-

eight hours. Necrosis appearing as a broad band, marked *N*, is very plainly to be seen. It extends entirely across the field, and portions of the necrotic tissue, to the right and left, can be seen to have already sloughed away. In this case the triangular opening was about one-half completed, and the whole mass, including the string, would have been detached within twelve to eighteen hours. A dark fold is seen in the centre of the necrotic path. This is an artifact, but it happens to serve as a guide to the necrotic part.

Fig. 9 shows a very satisfactory stoma measuring twelve centimetres in circumference. This is about as large as can be made in a dog, on account of the limited size of the gut. In the fresh state it easily admitted the first and second fingers together for their entire length. It appears incredible that such an opening should sensibly contract, although we shall not know the certain answer to the question of degrees of contracture of the stoma when the pylorus is patent until some experiments, for some time under consideration at the Surgical Research Laboratory, are completed.

The opening made by the twine triangular stitch, as shown in this specimen, seems to possess the advantages which are universally conceded to the openings made by the Murphy button and by the McGraw ligature. The button punches out and the McGraw gives length. There is no question that there has been a very distinct punching out in all the specimens made by the triangular ligature. Furthermore, as in the case of the McGraw, there is an element of length represented by the base of the triangle which may be made as long as desired. This cannot possibly be obtained by the ordinary Murphy button. That this long diameter is desirable is shown by the fact that Dr. Blake, in seeking to solve the question, devised a most ingenious modification of the Murphy button. It is so patterned as to give length to the stoma as well as breadth.

The pyloric opening is shown at *P* and the heavy rugæ or folds at *F*. This specimen was photographed partly because it yielded an excellent demonstration of the capabilities of the twine triangular stitch and partly because of these well-marked rugæ. It has been suggested that the twine, when

FIG. 8.—Note the line of necrotic tissue (about an inch wide) extending vertically through the photograph.

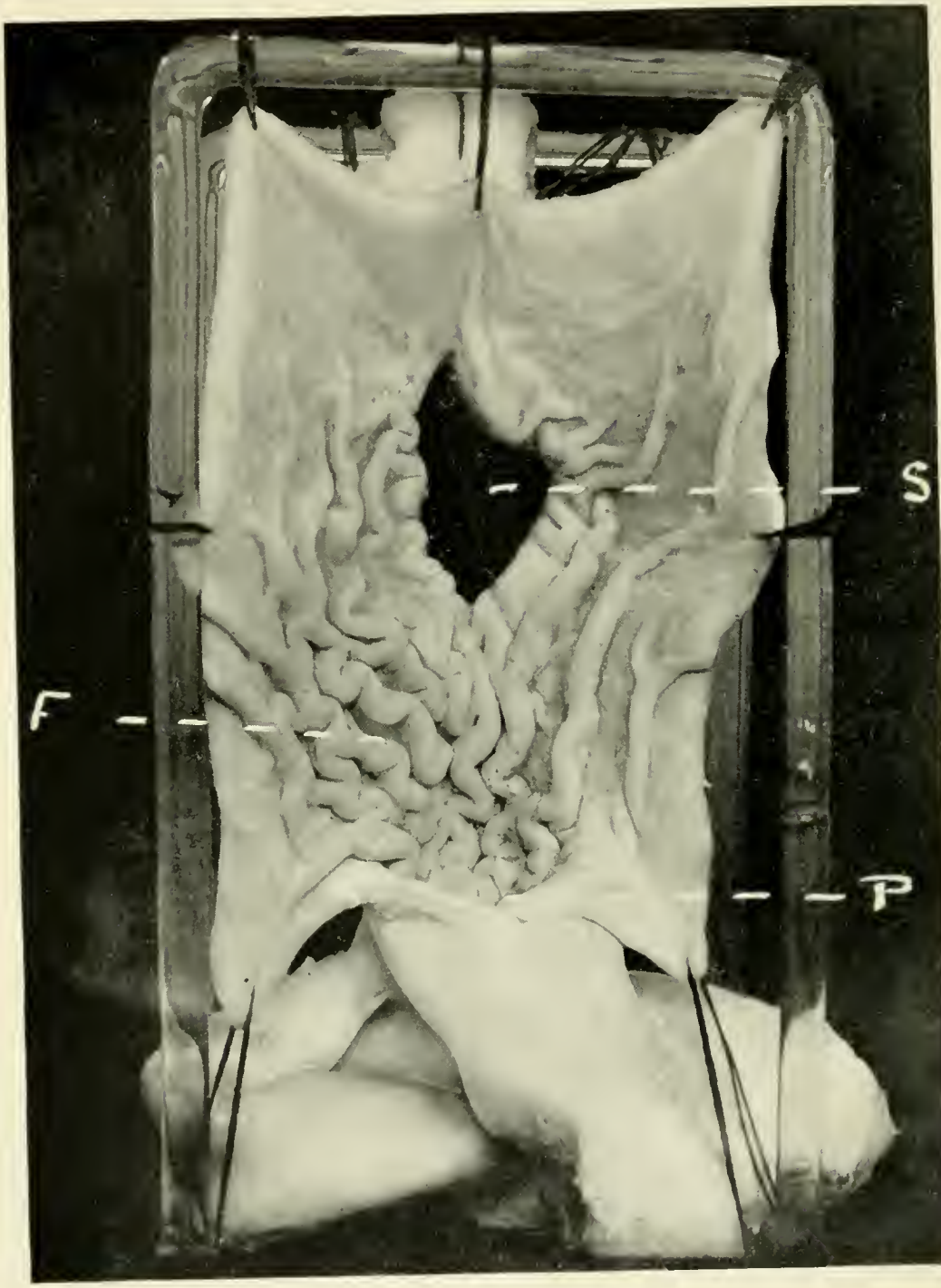


FIG. 9.—The stomach has been opened and the gut split. When retracted to the glass frame, the stoma shows clearly.

tightly tied, would pucker the mucous membrane and leave it in an undesirable condition. This stoma was made as near to the pylorus as convenient, and the photograph shows that the rugæ, while abundant at the lower portion of the stoma, are absent above, and, further, that they are more plentiful at the pylorus than at any part of the circumference of the stoma. It appears, after a study of this specimen and of others, that the suggestion, although apparently based on reasonable grounds, is, fortunately, a more theoretical than practical objection to the technique. Furthermore, inasmuch as the mucous membrane cannot grow together, if uninjured, even if tightly apposed, it seems justifiable to consider this objection as negated.

Fig. 10 represents a stoma which had been established for just three months. It will be noted that its edges are much smoother than those in the photograph just shown, and, furthermore, that the opening has become more or less spherical. The gastric mucosa, marked *G M*, has rolled a distance of about a centimetre into the duodenum. The dog, a large Newfoundland, lived without discomfort for about three months after the operation, and gained over ten pounds while under our care. *D* represents the cut and infolded pylorus, this operation having been done three days after the triangular stitch was inserted. As yet, we have been unable satisfactorily to block the pylorus except by section and infolding, silk and silver-wire ligation having been shown to be absolutely untrustworthy.

One of the most interesting conditions brought to light by this experimental work is the fact that in establishing gastro-enterostomy with the twine, unless the division of the gut be made thirty-five or more centimetres from the pylorus, the dog will die in from twelve to thirty-six hours, with symptoms resembling tetany. It is therefore necessary, in order to perform gastro-enterostomy with the twine and close the pylorus or duodenum, to do the work in two operations, separated by at least seventy-two hours. The twine must be put in first and the gut division done after the stoma is open. This is, however, not true if, as stated, division be practised thirty-

five or more centimetres from the pylorus. The discussion of this singular fact will be the subject of a subsequent communication from the Laboratory.

Fig. 11 shows a very interesting condition, already referred to, namely, the possibility of the retention of the twine triangular stitch at one of the apices of the triangle. The dog was a large, black Newfoundland, who licked the neighborhood of his wound continuously. The large hair ball, *C*, was fast in the loop of the ligature, *D*. *B* in this photograph shows the stump of the inturned gut. It will be noted in all these specimens that particular pains have been taken, in mounting, not to put any undue tension upon the parts, but to leave them sufficiently lax so that the normal relations shall not be disturbed. The stomata shown average about eight centimetres in circumference.

Fig. 12 represents a Y gastro-enterostomy. The two stomata shown at *S* and *S'*, as made by the triangular stitch, are seen to be perfect. The specimen, in addition to this, demonstrates an interesting pathological condition, and one which shows most pertinently the importance of experimental work on animals. The operation was completed by severing and infolding that portion of the proximal loop which lay between the entero- and gastro-enterostomy. The dog recovered so rapidly that it seemed hardly credible that an operation of such magnitude had been performed upon him. At the end of a week he was killed; his bowels and all other functions having been in perfect condition. *S M* is the stomach mucosa and *I* the intussusceptum, which, originally severed and unfolded about twelve centimetres from the stoma, had in a week's time, and without interfering with the health of the dog, turned itself inside out through the stoma into the stomach. Fortunately, the stoma, *S*, was sufficiently large not only to accommodate this mass, but to give a perfectly free opening for the passage of food as well. Dr. Brewer tells me that Crile has had this very accident happen on the human being; and this specimen supports Crile's contention that this operation should never be done without subsequently attaching this free portion of the proximal loop so as to prevent its invagination.

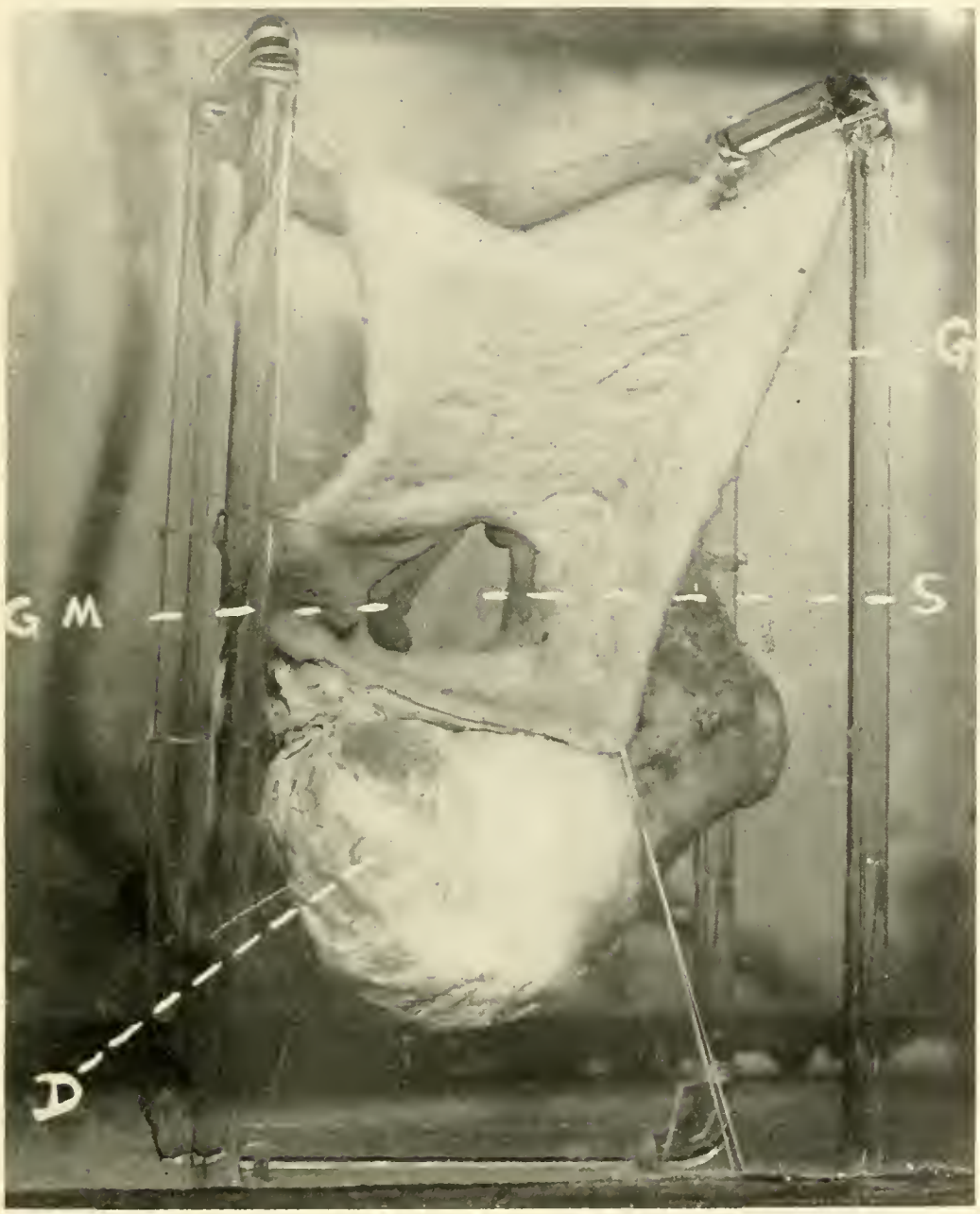


FIG. 10.—Gastro-enterostomy. Note evagination of gastric mucosa showing desirability of a "punched-out" opening.

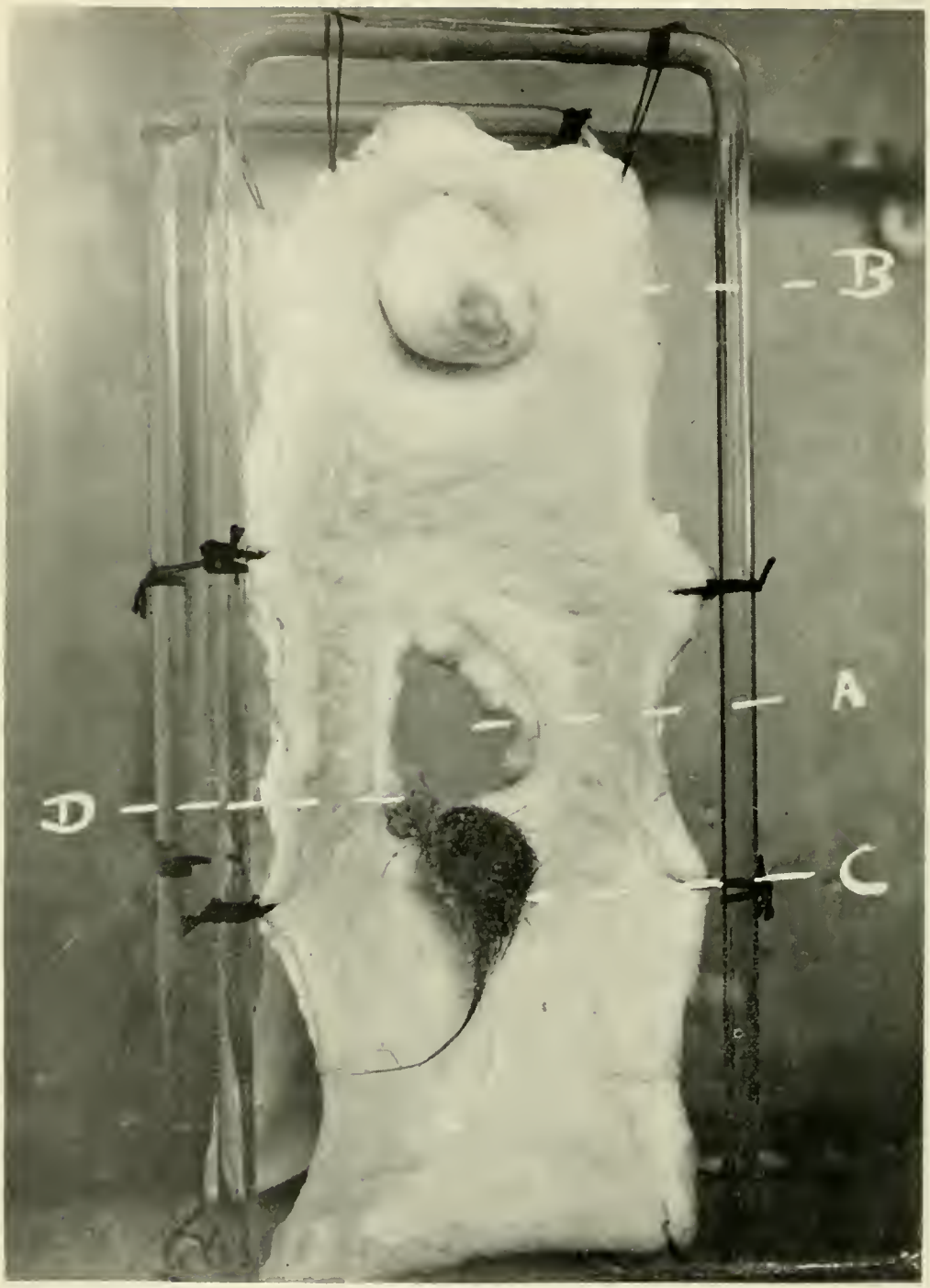


FIG. 11.—Gastro-enterostomy. Looking towards mucosa of stomach and through "stroma." Note hair-ball.

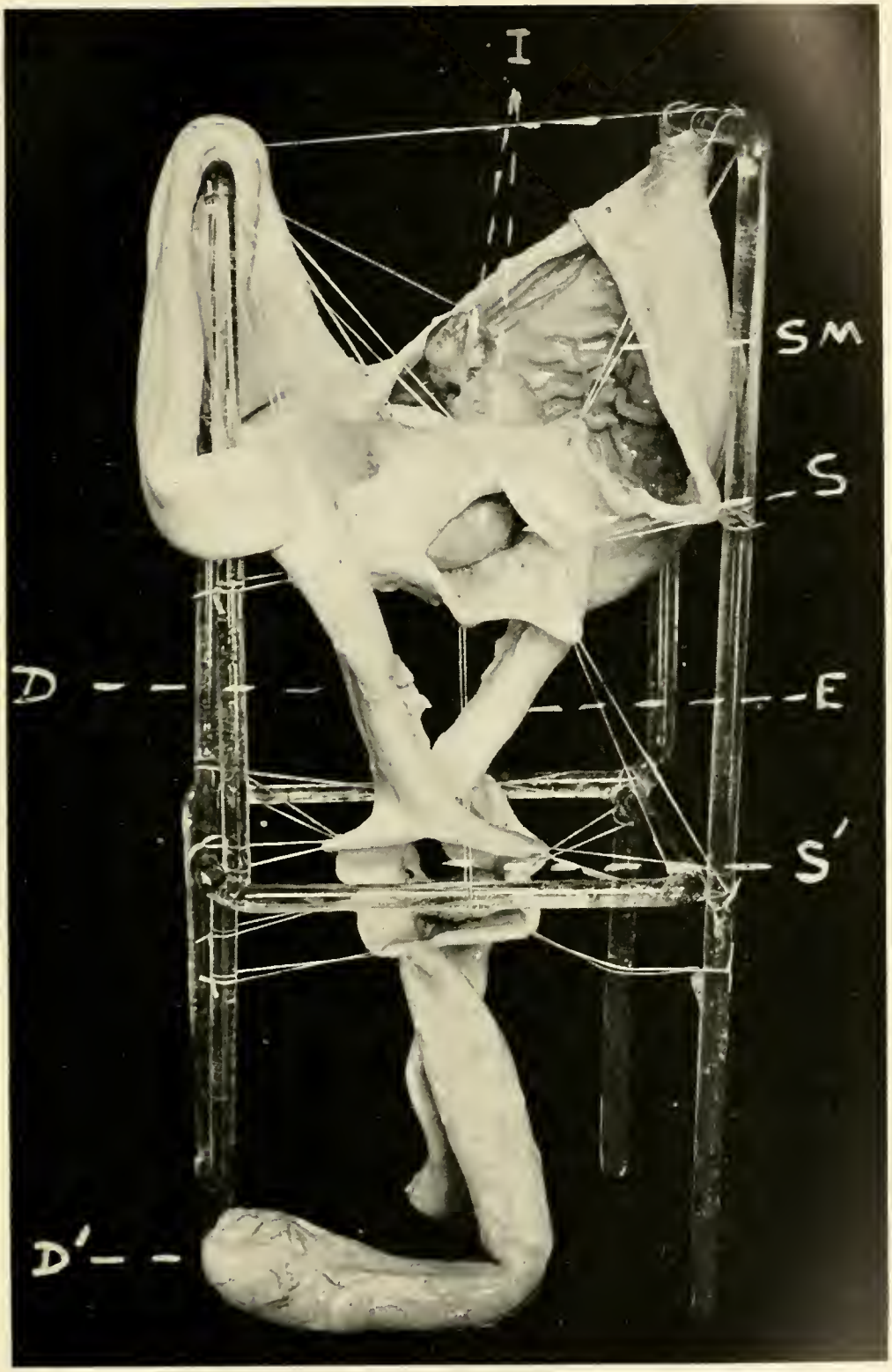


FIG. 12.—Y operation. Note invagination.

This Y gastro-enterostomy can be done more rapidly with the twine triangular stitch than by the ordinary end-to-side anastomosis. The two stomata and the folding in require, at the outside, ten minutes each. Obviously, this method closes the alimentary canal absolutely for at least forty-eight hours. In the case of the dog, such closure as already cited results in death from tetanoid symptoms. It was at the instance of Dr. George E. Brewer that these Y gastro-enterostomies were attempted. Not wishing to leave as much as thirty-five centimetres between the pylorus and the site of the intestinal division, the amount of gut already alluded to as necessary to prevent death, pending the cutting out of the twine ligature, we have, in several instances, had recourse to the following modifications of the usual technique. Immediately after the insertion of the triangle and before the apices are tied together, we have lifted the centres of the triangles with a mouse-tooth forceps and cut out a small piece of the wall with curved scissors. Immediately after this the knot in the twine ligature is tied. It might reasonably be thought that the tying of the twine would obliterate the opening between the opposing viscera. Enough experimental work has not been done upon this point to warrant positive statements, but in two cases in which it has been employed an opening has been made in the viscus and a blunt instrument, an artery clamp, has been gently passed down to the region of the ligature and has slipped through into the opposing organ without any force whatever being used. The tying of the twine does not, therefore, necessarily occlude the lumen which has been made in the opposing triangles as described.

Immediate and justifiable exception to this technique is anticipated by stating that we have had no less than three deaths from peritonitis due to leakage around the single row of Lembert stitches. If, therefore, this technique be employed, it may already be positively stated that a double row of Lembert stitches must certainly be employed. We had hoped that the twine ligature would play the part of one of these rôles, but the difficulty is that the mucous membrane pouts so that, although tied tightly, it does not control leakage. About 50 per cent. of the cases in which the triangle has been cut out

have resulted in perforative peritonitis. A double row of sutures has not yet been experimented with.

Shock after Operation.—We have learned not to operate on dogs until after they have been in the cage (described in ANNALS OF SURGERY, June, 1904) and on a diet of Sprat's Dog Biscuits for at least three days. Whether the increased resistance which certainly develops after this period is due to the animal's becoming accustomed to his environment, or whether the very excellent biscuits are responsible for it, is not known. Dogs operated upon, under the limitations above described, suffer no shock, and appear to have no pain after the twine triangular stitch has been put in. As a rule, within twelve hours of the time of operation they drink water and in twenty-four hours take milk freely. The absence of shock and pain is a well-known characteristic of the McGraw elastic ligature, and is, therefore, naturally to be looked for if twine be employed in its stead. There is to be expected in dogs, and in human beings as well, a moderate amount of vomiting of brown material.

The clinical reports from the cases operated upon by Drs. Bodine, Lilienthal, Abbe, and Meyer show an absence of shock in human beings equal to that observed in dogs when twine is employed.

Character of the Twine.—At the Laboratory we make use of strong white twine, used in the dissecting-room for suspending the extremities of subjects. If the braided line be used, 22-thread Cuttyhunk is recommended. What we have used is twisted, not braided. Neither the writer nor any of the students have yet been able to break it with the hands. Dr. Abbe used this twine in his recent case, and was also unable to break it even with his gloved hands. It is important that the twine used should be as strong as this, because, as recorded in one of Dr. Lilienthal's cases, the silk broke while he was inserting it. An advantage of using a twisted rather than a braided twine lies in the fact that, in all probability, tighter pressure can be made upon the tissues to be constricted with the twisted material. It offers less resistance to the tissues, and, furthermore, causes less friction upon itself when the first knot

is made taut. A possible objection to it, and one which we have on one occasion encountered at the Laboratory, lies in the fact that during its insertion the twine may uncoil slightly and the operator may, as already stated, inadvertently pass the needle through one of the coils without encountering sufficient resistance to realize it. It has become our custom, therefore, in view of this accident, to seize the stitch at about its centre with a thumb forceps and make sure that it is entirely free before the twine is tied.

Advantages of Using Twine instead of Elastic.—That a piece of twine eight or ten centimetres in length, if it will do equally good work, is to be preferred to any form of metallic button, is hardly to be denied. This is true whether the ordinary instrument devised by Dr. Murphy be used, the equally ingenious collapsible aluminum bobbin of Dr. Harrington, or even the new French button in the form of a key-ring. Intestinal obstruction and death have been caused simply by the weight of the Murphy button. Aside from the fact that these instruments are likely, on the one hand, to slough into the peritoneal cavity, or, on the other, not to loosen from their attachment, or even, perchance, to fall into the stomach, there is one inalienable characteristic common both to the metallic adjuncts and to the McGraw elastic ligature as well. Success of the operation depends, in great part, upon the intrinsic characteristics of the instrument or material, and by no means entirely upon the skill of the surgeon. He is, in other words, in great measure dependent upon an instrument maker or upon a dealer in india rubber. If the twine triangular stitch fails, however, the operator has no one to blame but himself. He has not tied the twine tight enough, if the stoma fails to be created. In other words, the twine triangular ligature depends for its success entirely upon the skill of the man who is putting it in, and not upon the problematical strength of an elastic band or upon the variable temper of a spring, as in the case of the Murphy button. Furthermore, a piece of twine may be had anywhere and upon all occasions, whereas the elastic ligature must be procured from a special maker, must be flawless, and, above all things, must be new. Ligatures which have been

imported to the Laboratory directly from Detroit broke while being inserted after they had been in our hands less than five weeks.

Dr. John A. Bodine had a similar experience at the Polyclinic Hospital while endeavoring to insert a McGraw elastic ligature which he had on the very day of the operation obtained from one of the leading instrument houses of this city.

The Results of the Insertion of the Stitch in Human Beings.—The following named gentlemen have used the technique, and have kindly signified their willingness to allow me to report their cases: Dr. John A. Bodine, Dr. Howard Lilienthal, Dr. Robert Abbe, and Dr. Willy Meyer.

Dr. Bodine was the first surgeon to use the stitch on a human being. The history of his case, as abstracted from the Polyclinic Hospital Records, is as follows:

Case I.—Mrs. C. G., admitted June 1, 1904, to the Polyclinic Hospital, found to be suffering from pyloric stenosis and assigned to the medical side. Her weight was eighty-five pounds. She was given strychnine, hydrochloric acid, and potassium iodide by enema, and put on a diet of broth and buttermilk; gastric lavage. On June 9 she weighed ninety pounds; on June 21 she was discharged improved.

On October 3 she was readmitted to the Polyclinic Hospital, and assigned to the service of Dr. John A. Bodine. She had lost all that she had gained during her previous visit to the hospital, was exceedingly weak, and seemed in a dying condition. Patient said she had been unable to retain anything, and had vomited almost continuously for the last three months; she complained of a constant pain over the region of the pylorus, which was so severe that she was willing to have operative intervention. On palpation, the abdominal walls were found rigid; nevertheless, a very distinct tumor in the region was easily mapped out. It was extremely tender but not entirely fixed. The urine was normal, although much diminished in amount. Owing to the extremely debilitated condition of the patient and to the fact that the tumor was palpable, no examination was made of the gastric contents; but the patient was operated upon just as soon as she had rallied from the exertion of her journey to the hospital.

On October 5 the triangular stitch was inserted by Dr. Bodine, and tied as tightly as possible. A posterior gastro-enterostomy was made without entero-enterostomy; time of operation, thirteen minutes.

October 6, vomiting; pain; sterile water given freely, as it made the vomiting easier and modified the thirst; temperature normal; pulse, 96. October 7, nausea and vomiting; patient very weak; oxygen given; vomited frequently small quantities of dark material. This was evidently the slough from the stitch. October 8, continued vomiting a black material. Late in the afternoon very tympanitic and restless; continued regurgitation. On the night of the 8th, or seventy-two hours after operation, she fell asleep, and awakened much brighter and more comfortable. This undoubtedly marked the period of the falling out of the slough.

From this time on the history of the patient was that of uninterrupted convalescence. An interesting point to be observed was that, during the third day, she was given twenty-four ounces by mouth and actually vomited up twenty-six, the additional two ounces being, supposedly, secretion from the walls of the stomach. The patient has recently reported herself as being able to attend her household duties without fatigue; she has gained forty-five pounds, and can eat corned beef and sauer-kraut with perfect comfort.

The clinical diagnosis of carcinoma of the pylorus made at the time of operation, but based more particularly upon the clinical evidences, is probably erroneous. Owing to the patient's extreme prostration at the time of operation, almost no examination of the parts seemed justifiable. The entire pylorus was, however, blocked by a large tumor, and the stomach was moderately dilated.

Case II.—Mr. J. L.; bookkeeper; aged forty-nine years; admitted to Mt. Sinai Hospital, and transferred to surgical division, December 14, 1904; discharged January 7, 1905. Diagnosis, pyloric obstruction from carcinoma. Operation, gastro-enterostomy by Maury's triangular stitch.

Family history negative. Previous history negative.

Present illness. One year ago began to note gradual loss of

health and strength. Pain in the upper right abdomen became pronounced, and was particularly marked ten or fifteen minutes after eating; flatulence was almost continuous. There was at no time hæmatemesis or vomiting; constipation had been marked, and œdema of the legs had been occasionally present; he had lost eighteen pounds.

Physical, December 4, 1904. Cachexia. No icterus. Abdomen, inconstant visible peristalsis. Stomach percussion note two inches below umbilicus. Inflation and transillumination made outlines very distinct. This was seen with particular clearness after the administration of a fluorescent medium.

Laboratory findings. Free hydrochloric acid absent; lactic acid present. Total acidity, 60. Guaiac test positive. Urine negative.

Operation, December 14, 1904. Dr. Howard Lilienthal. Posterior gastro-enterostomy by Maury's triangular stitch.

December 15. General condition good; practically no reaction to the operation whatsoever.

December 27, patient out of bed and eating.

January 6, 1905, discharged, improved.

Case III.—J. H.; aged fifty-nine years; admitted to Mt. Sinai Hospital, February 15, 1905; died February 21. Diagnosis, gastric carcinoma. Operation, gastrectomy and posterior gastro-enterostomy by Maury's triangular ligature.

Family history negative. Previous history, typhoid twenty-five years ago.

Present attack began eight months ago. First symptom, vomited one-half hour after eating breakfast, retained other meals. Eructations and general evidence of dyspepsia shortly followed. Pain for last month only. Starts from epigastrium and radiates to sternum. Constipation. No movement for past eight days. Loss of strength rapid and marked.

February 14, stomach analysis; no free HCl. Blood and lactic acid.

February 15, two quarts of dark grumous fluid with rancid smell removed from stomach. Modified Ewald. Total acidity, 84. Guaiac positive. Boas-Oppler and muscle fibres present.

General physical negative. Patient has lost much weight and has distinct cachectic look.

Operation, February 17. Dr. Howard Lilienthal. Distal

one-half of stomach resected. Gastric wound closed by three layers of silk sutures. Duodenal stump closed with purse-string ligature and cauterized with pure carbolic. It could not be turned in. Maury's twine triangular stitch was inserted between the remaining gastric pouch and the upper portion of the jejunum. A drain was passed down to the duodenal stump and the abdominal wound closed.

February 18 to 21, patient's condition progressively bad. Very foul odor to the drain-tube when removed at first dressing.

Patient died February 21. Wound examination revealed general purulent peritonitis, which was shown to have had its origin in a small fistula through the gastric line of suture. This opening easily admitted a good-sized probe and communicated directly with the peritoneal cavity.

The gastric walls were very œdematous as well as hypertrophied. They were approximately double the usual thickness. The Maury triangular stitch had not yet sloughed out, although the triangles were distinctly necrotic and drainage had begun at the angles.*

Case IV.—J. C.; aged thirty-three years; tailor; admitted to Mt. Sinai Hospital, February 22, 1905; discharged, March 14. Result, cured. Diagnosis, pyloric stricture. Operation, gastro-enterostomy by Maury's twine triangular ligature.

Previous history. Typhoid fifteen years ago.

Present illness. Onset five months ago with sharp pain in right hypochondrium radiating to right shoulder. No jaundice. Pain has become progressively worse. Patient in bed for most of the time for last three months. Vomited frequently.

Physical. General condition good. Glands negative. Abdomen normally tympanitic.

Operation, February 24. Dr. Howard Lilienthal. All structures in neighborhood of pylorus found adherent by bands of adhesions. Transverse colon included in mass. When adhesions were freed, which was accomplished with great difficulty, pylorus was found to barely admit tip of finger. Mass now determined to be in wall of pyloric portion of the stomach. The triangular stitch was inserted.

* This operation was justified by the fact that Ochsner had reported the successful employment of a similar technique, using the McGraw ligature instead of the twine.

Postoperative history. There was practically no reaction from the operation. This patient was very noisy and suffered intense pain before operation. This continued for a short time after the insertion of the ligature, and to it was added vomiting of a moderate amount of coffee-ground fluid. Six days after operation patient had two severe attacks of pain, which was located in same situation as before operation.

March 8, twelve days after operation, silk ligature was found in stool, a dose of castor oil having been administered. The ligature had undergone extensive digestive processes.

March 13, discharged cured.

Case V.—D. F.; aged fifty-five years. Diagnosis, pyloric stenosis and periduodenal abscess. Admitted to Mt. Sinai Hospital, March 6, 1905. Died March 29.

Previous history, typhoid thirty years ago.

Present illness. Unable to sleep for last two months owing to pain in right side. No hæmatemesis or melæna. Pronounced nausea but no vomiting, except in last three weeks, during which time has vomited twice.

Physical, March 8. Well nourished. Few small glands in submaxillary triangle, axillæ, and groins. Sense of resistance in abdomen and pronounced tenderness. Hæmoglobin, 92 per cent. White blood-corpuscles, 8600. Test meals, free HCl, 70. Combined acid, 10. Total acidity, 95. Microscopic, occasional red blood-corpuscles.

March 14, distinct hard globular mass, palpable just above and to right side of umbilicus.

Urine. Albumen present. Large hyaline and small granular casts.

Operation, March 22, 1905. Dr. Howard Lilienthal. Thickened stenosed pylorus high above liver, making external palpation of mass difficult. Maury's twine triangular stitch inserted posteriorly.

March 23, patient reacted poorly owing to nephritic involvement. Nauseated, noisy, stupid. Vomited coffee-ground material.

March 24, condition bad, face twitching. Labored, rapid breathing; high tension pulse.

March 27, uræmic symptoms less marked. Very weak but better.

March 28, general condition not satisfactory. Fluid in lungs. Melæna. Primary union of wound.

March 29, patient died in afternoon.

March 30, wound examination. Pylorus involved in large abscess cavity, which seemed to have sprung from a gastric ulcer. It was entirely walled off from the peritoneal cavity. The Maury stitch had not entirely cut through, but necrosis of the enclosed triangles was pronounced, and there was drainage at the angles.

The material employed in making this stitch was heavy silk. It had broken when first tied, and when introduced the second time could not be tied as tightly as the technique requires. This accounts for delay in total sloughing of the triangle, and shows that even the heaviest pedicle silk is not strong enough to employ for the triangular stitch technique.

Case VI.—G. W.; aged forty-two years; born in Ireland; occupation, iron-moulder. Admitted to St. Luke's Hospital, February 16, 1905. Operation, March 1. Died March 4.

Family history negative.

Past history, scarlet fever and whooping-cough. At age of ten years severe typhoid, no complications. For the past twelve years has been subject about once a month to sour stomach, eructations of gas, and feeling of fulness in throat shortly after eating. Nasal catarrh at intervals for the past four years. Since boyhood has had occasional swellings of left scrotum with tenderness lasting from a few hours to one-half day with no relation to time of day, position, nor straining. Bowels regular up to June. Non-alcoholic, non-venereal, small eater, no renal, pulmonary, or cardiac diseases.

Present history. In June, 1904, had an attack of severe nausea with vomiting and pain in the right side extending up to the epigastrium. Similar attacks recurred once or twice a day, lasting usually about half an hour, most frequent during the night, from June to October. Pain was burning in character. During October pain became less and less frequent, disappearing by November. During latter month and December was entirely free from trouble, regaining twenty-five pounds lost from June to October.

January 1, 1905, following eating of some cheese, had similar attack of severe nausea, with vomiting and recurrence of pain

in right side and epigastrium. Eructations of gas were frequent and annoying. Up to present time (February 16) has had two attacks daily, usually at night. Pain in side not so severe as in former attacks; has lost about twenty-five pounds since January, and has taken medicine to keep the bowels open.

Chief complaint. Frequent attacks, usually nocturnal, of nausea, vomiting, pain in right side, eructations of gas.

Gastric analysis, negative. Free hydrochloric, 44. No lactic acid.

Operation, March 1. Maury's twine triangular ligature, Dr. Robert Abbe.

The stomach was found to be markedly dilated, and the pylorus would not even admit the tip of the little finger. The triangular stitch was placed between the posterior gastric wall and the upper portion of the jejunum, and an entero-anastomosis between the distal and proximal loops was made. Entire time of operation, twenty-five minutes. Patient reacted well after operation. Vomited a little coffee-ground material, but had no pain or discomfort worth naming. Forty-eight hours after operation the temperature suddenly shot up. The patient's general condition became very bad, and 100 hours from time of operation he died.

Post-mortem by Dr. Wood, the hospital pathologist. Lungs showed an acute diffuse pneumonia grafted upon an old and bilateral tuberculous lesion. The pneumonic process was very extensive and was the cause of death. Capacity of stomach, 2200 cubic centimetres.

The triangular ligature had not cut through nor had drainage begun at the angles.

Microscopic examination of the tissues contained in the triangles showed that necrosis in the path of the twine stitch was well advanced. Sloughing of the included tissue would have taken place had not death, due to pneumonia, arrested the process.

Case VII.—Mrs. C. W., aged forty-five years, admitted to the German Hospital, April 22, 1905; married; two children, both in good health; has had more or less stomach trouble since her fourteenth year, after an attack of scarlet fever. For last two years has had more trouble from stomach, with steady loss of flesh and strength; occasional vomiting, but never blood. Always constipated; frequent pain in epigastrium and back and

especially in left side of abdomen; taking food caused considerable distress and eructation of gas, but no vomiting; pain, however, was apparently independent of food-taking. Progressive increase of symptoms. Status præsens, anæmic, slightly icteric woman; small, very hard mass, about the size of a mandarin, is situated in epigastrium, slightly to the left, very irregular, descends with deep inspiration; spleen not enlarged; liver not palpable; some enlarged inguinal glands.

Operation, April 26, Dr. Willy Meyer. Incision above umbilicus; stomach low; middle of small curvature seat of infiltrating mass, firmly attached to spleen, which also seems somewhat hard. Stomach drawn inward at this place, slightly hour-glass-shaped. Many infiltrated glands. Diagnosis doubtful: malignant tumor or ulcer, perhaps carcinoma or basis of old ulcer. Posterior gastro-enterostomy difficult on account of adhesions between transverse mesocolon and gastric wall; an irregular portion can be pulled forward through the rent in the mesocolon and stitched to the latter's border; about ten posterior, interrupted silk sutures. Then gastro-enterostomy with the help of twine, according to Maury; continuous silk suture in front. Additional entero-enterostomy by means of elastic ligature, about fifteen centimetres away from new anastomosis.

Patient stood operation well. Pulse 84 at completion of operation.

April 28, doing very well indeed; normal pulse and temperature.

Postoperative history.—April 28, patient vomited intermittently. This continued until May 1. Daily lavage. On May 1 the vomitus had a distinctly fæcal odor. On May 2 there was little blood in vomit. On May 3 she had a violent vomiting spell while her stomach was being washed. From that time on the vomiting suddenly ceased, and she passed on to uneventful recovery. On May 13 patient had not yet passed either the twine ligature or the elastic ligature. She was able to eat all kinds of solid food without the slightest discomfort, and she stated that now, for the first time in two years, she had been able to take solid material without subsequently vomiting it.

Case VIII.—Mrs. X.; housewife; French Alsatian; thirty-five years of age. Simple stricture of the pylorus of several years' standing, during which time she had been subjected to every sort of treatment. Operation, Maury's triangular stitch, by Dr. Joseph

J. Noll, May 16. Anterior gastro-enterostomy without entero-enterostomy. The stitch was placed near the pylorus. Postoperative history was uneventful except for obstinate vomiting; the patient's pulse, however, remained below 100 throughout. The twine had not passed by rectum. There was every clinical evidence that it had cut through on or about the fourth day. Dr. Noll regarded the operation as perfectly successful.

A study of these eight cases shows that the stitch takes somewhat longer to cut out in man than in animals. The explanation of this probably is that the human stomachs operated upon have been very much thickened, and therefore more resistant than the normal animal organ. Dr. Lilienthal has demonstrated that silk should in no case be used, and that a loosely twisted linen twine which cannot possibly be broken by the hand is the material of choice. He has further demonstrated that the less twist there is in the twine, or, in other words, the straighter the fibre, the less disposition is there for it to stretch after it has been inserted.

The mortality attending these operations has been high. In Dr. Lilienthal's first case it was due, in his own words, to an error in judgment in closing the alimentary canal, although it may be noted that the walls of this stomach were so œdematous that a failure of union was almost to be looked for. The triangular stitch had not sloughed out in this case, but necrosis of the triangles was well advanced, and there was drainage at the angles.

Dr. Lilienthal's second fatal case is seen to be due to the nephritic involvement following prolonged abscess formation. Here again drainage had begun through the angles of the triangles and necrosis was well advanced.

In Dr. Abbe's case, which lived 100 hours, there is positive microscopic evidence that the triangles would have sloughed out had the patient not succumbed to anæsthetic pneumonia.

Dr. Meyer, as is well known, has for years been a stanch advocate of the McGraw elastic ligature. While talking with him about the advantages of the twine in the place of the ligature, he said that last year, while operating for Professor

Von Bergmann, he had asked him to demonstrate the McGraw technique. No suitable elastic being at hand, a very inferior and questionable piece was made use of. Dr. Meyer said that this occasion called to his mind very forcibly at least one of the advantages of the twine over the ligature, namely, that it is always available. It is with pleasure that I quote the following lines from a letter recently received from Dr. Meyer: "I take this opportunity of once more expressing to you my compliments on having devised this excellent method. I certainly consider it an important addition to our operative resources in gastro-enterostomy."

It must never be lost sight of that the success of the technique depends entirely upon tightening the knot with all one's strength.

SUMMARY OF LABORATORY CASES.

From the 10th of November, 1904, to the 24th of February, 1905, twenty-nine dogs and one hog were operated.

On seventeen dogs, the twine triangular gastro-enterostomy was done, and in thirteen of these the pylorus or some region of the upper gut was tied off, either at time of operation or at a subsequent period.

The Y gastro-enterostomy has been done on five dogs.

Seven dogs were experimented upon in connection with other work.

In one hog two gastro-enterostomies were done February 2. The animal is still in excellent condition.

Of all these dogs, four died as the result of evagination of the cut ends of the gut. Three died of the tetanoid symptoms referred to.

Three died owing to faulty technique, gut punctures, etc.

Fifty per cent. of the dogs who underwent the modified technique of cutting out the centre of the triangle died of peritonitis.

No dogs have died of peritonitis directly the result of the twine triangular stitch.

There has been one failure of the stitch to cut out, owing to its not being tied tight enough.

TETANY PARATHYREOPRIVA:*

A CASE REPORT, WITH A BRIEF DISCUSSION OF THE DISEASE AND OF THE PARATHYROID GLANDS.

BY EUGENE H. POOL, M.D.,

OF NEW YORK,

Attending Surgeon to the French Hospital, New York; Instructor in Surgery in Columbia University.

THE acquisition in recent years of an anatomical knowledge of hitherto unsuspected organs, the parathyroid glands, has engendered much investigation as to the physiological rôle and pathological import of these bodies. Dependent upon such studies, interest has coincidently centered on the subtle question as to the explanation of certain nervous manifestations which attend the removal of these structures in animals. The condition thus artificially produced appears to be of the same nature as a group of symptoms which occasionally occurs in man. These symptoms were first described by Steinheim[1] in 1830, and the name tetany was subsequently given to them by Corvisart.[2] Since then the same clinical picture has been repeatedly noted in association with various conditions of widely different character. For example, it has been seen to occur with severe gastro-intestinal affections, especially dilatation of the stomach, with pregnancy and the puerperal state, with some acute fevers, with various nervous diseases, and after removal of the thyroid gland.

The cause of its occurrence in most of these conditions is not understood. As a sequel, however, to thyroid operations it has been definitely, ascribed to the removal of the parathyroid bodies, and in consequence has been designated by Erdheim[3] tetania parathyreopriva.

Observation of a case which recently came under my care

* Read before the New York Academy of Medicine, May 2, 1907. Through the courtesy of Prof. T. M. Prudden and Prof. J. A. Blake the work for this paper was done in the Pathological and Surgical Research Laboratories of Columbia University.

gave rise to an effort to collocate the clinical features and therapeutic possibilities in this variety of tetany. To do this clearly it seems necessary to supplement such considerations with a review of the history of the subject and of the anatomy, development, and theories as to the physiological rôle of the parathyroid glandules.

Case Report.—The patient, a seamstress by occupation, is a Swiss, thirty-three years of age. She was referred to my service at the French Hospital by Dr. Fellowes Davis, in April, 1906. The significant features of her history are as follows:

In 1903, she had considerable pain in the lower part of the neck and marked dyspnœa and dysphagia. For some time previous to that there had been a large tumor in the region of the left lobe of the thyroid gland. An operation was performed in Bern, Switzerland, and a tumor on the left side of the neck was removed. This was undoubtedly the left lobe of the thyroid. For one year after the operation she was relieved of her symptoms, but during the second year the dyspnœa, dysphagia and swelling returned and increased to such an extent that operation became imperative.

Besides the features mentioned above there was nothing of importance in her history. Though in childhood a number of operations had been performed upon her eyes, the last of which was eighteen years ago, she had always enjoyed good health and had never suffered from any nervous troubles.

Physical Examination.—The woman was thin and pale, her expression anxious, breathing labored, the sternomastoids prominent. There was a slight rounded projection, about one and a half inches in diameter, just above the sternum, and a faint scar of the incision of the former operation could be seen. The mass, which reached beneath the sternum, was firm and nodular and moved with the larynx on swallowing. The examination was otherwise negative.

On March 3, 1906, I operated under ether anæsthesia and exposed the thyroid by a curved incision. In the region of the isthmus there was a round, smooth mass, about two and one-half inches in diameter, which was to a great extent bound down by cicatricial tissue; it extended downward behind the sternum and

FIG. 1.

Tetanic spasm, showing flexion of wrist.

FIG. IV A.

Method of producing a tetanic spasm in feet by stretching the sciatic nerve by means of forcible flexion of trunk on thighs. Taken immediately on sitting up, before occurrence of spasm.

compressed the trachea. The left lobe of the thyroid was absent. Before any tissue was removed the right lobe was thoroughly exposed and found to be of normal size, appearance, and consistency. Accordingly, the thyroid gland was clamped at the junction of the isthmus and the right lobe, and cut across as close to the tumor as possible. Before doing this it was found necessary to ligate the inferior thyroid artery which ran close to the tumor. The whole of the right lobe, except a small part which lay close to the isthmus, was left. The wound was closed with drainage.

Postoperative Course.—The healing of the wound was uneventful. On the fourth day after operation, tetanic contractures occurred in both hands, which assumed an attitude similar to that produced by stimulation of the ulnar nerve, an attitude sometimes called the accoucheur's hand, since it is the same as the position taken for making a vaginal examination. Throughout the disease this was the usual contraction of the hands. The spasm was accompanied by cramp-like pains in the hands, and occasional twitching of the facial muscles, with some neuralgic pains in the right side of the face. This condition was present whenever the patient was seen during the next twenty-four hours, when cramps in the feet and calves occured together with forcible plantar flexion of both feet which lasted for about five minutes.

After that for about thirteen months the patient presented the typical clinical features of tetany. Of the symptoms, the most conspicuous were bilateral and symmetrical contractions of the flexor muscles of the hands, wrists, and feet (Figs. I, II and III), as previously described, preceded and accompanied by cramp-like pains in the affected muscles. To these spasms were added at times attacks of more general contractures, occasionally with cyanosis which necessitated the administration of chloroform, attacks of asthmatic breathing, of tetanic spasms of the muscles of the face, jaw, neck and back, slowness and thickness of speech, difficulty in swallowing, but apparently no dullness of mind. The skin and hair seemed unchanged beyond a slight growth of hair on the chin and upper lip. There was for several weeks marked edema of the left wrist and hand, and redness over the knuckles of this hand. Chvostek's and Trousseau's signs were present and typical almost all of the time. Thus, the facial muscles, as

a rule, contracted rapidly to mechanical irritation by tapping over the facial nerve; and by steady pressure on the nerves and vessels of the arm the usual contracture of the hand was brought on in about one-half to three minutes, sometimes with distinct fibrillary twitching over the thenar eminence. In this test, cramp-like pains regularly preceded the spasm which developed gradually and not suddenly. Contractures also resulted from making the sciatic nerve tense by holding the patient in a sitting position, so that the trunk and thighs were flexed beyond a right angle, with the legs extended; or by putting the nerves of the brachial plexus on the stretch by elevating the arm above the head with the forearm extended (extreme abduction). Figs. IV and V.) The contracted muscles were always board-like to the touch. Unfortunately, tests with the galvanic current were not made; but Dr. J. A. Booth reported on February 8, that with the faradic "even mild currents brought on tetanic contractions in both upper and lower extremities, showing a decided increased electrical excitability."

The above symptoms occurred in attacks at variable intervals. During the first six weeks and the last three months of the disease, there were from one to five attacks almost every day. The duration was from several minutes to several hours. During the intervening seven months, when the patient was not in the hospital, they were much less frequent, but prevented her from working.

About five weeks ago the attacks of typical tetanic spasms gradually ceased; the other tetanic symptoms also gradually disappeared, and Chvostek's, Trousseau's, and the other two tests mentioned above, became less marked, and now elicit no response. Moreover, the electrical tests made by Dr. Booth on April 23, showed only slightly increased galvanic irritability in nerves and muscles, the most marked being in the ulnar nerve ("Ca Cc>An Cc, 3 Ma").

Hysterical symptoms of various kinds have, however, become marked and are now striking. This is not surprising considering the prolonged sickness and the frequent use of hypnotics and other drugs. This condition, however, is improving under the care of Dr. Booth.

As regards treatment, the following were tried: various thyroid and parathyroid preparations by mouth and hypoderm-

FIG. IV B.

Method of producing a tetanic spasm in feet by stretching the sciatic nerve by means of forcible flexion of trunk on thighs. Taken 1½ minutes later, showing onset of spasm.

FIG. V.

Method of producing tetanic spasm of hand by stretching the brachial plexus by means of forcible abduction of arm, showing accoucheur's hand.

ically. The parathyroid material was supplied by Prof. Vassale, of Modena, by Dr. Beebe, of New York, and by Armour and Co. One saline infusion of twenty-four ounces was given, and five parathyroids were implanted subcutaneously. These were removed aseptically immediately after death from three accident cases, put at once into ascitic fluid, and implanted as soon as possible. Under general anæsthesia the implantations were made into the abdominal wall and the lobe of the ear. In the latter case a deep incision was made along the lower free margin of the lobe so as to divide it into two lips. Cocaine was not used on account of the disadvantage which might result from the infiltration of the tissues. The parathyroids, while in the ascitic fluid, were cut so as to expose two or more raw surfaces; the technique differed in this respect according to the size of the gland. The lobe of the ear seemed to present a particularly favorable site for the implantation because a perfect and permanent opposition of the implanted parathyroid and the two surfaces of the wound was readily obtained by gentle pressure produced by an appropriate dressing. All the wounds healed by primary union. The first two implantations were made on March 1; in this case the operation was finished ninety minutes after the death of the patient from whom the tissues were taken. The other three implantations were made on April 17.

The improvement which occurred about one month ago,* that is, the gradual disappearance of the true symptoms of tetany, was coincident with the repeated administration of Beebe's nucleo-proteid in large doses by hypodermic, and occurred from four to six weeks after the first implantation. No effect could be attributed to other therapeutic measures.

Historical.†—Operations for goiter were uncommon until about 1877; but since then, due largely to the impulse of Billroth and Kocher, they have progressively increased in frequency. The occurrence of tetany after such operations was first recognized by Weiss [6] in 1880. About three years later, Kocher [7] and Reverdin [8] called attention to the condition since known as

* This paper was read May 2, 1907.

† Since exhaustive histories have been published several times, only a résumé is given here, and the reader is referred to such articles as those by Erdheim,[3] Jeandelize,[4] and Welsh,[5] for a more detailed account.

cachexia strumipriva, and this was shown by Kocher to be a frequent sequel to complete thyroidectomy. The two diseases, tetany and cachexia strumipriva, were regarded for a considerable time simply as different phases of one condition which was supposed to be dependent upon insufficiency of the obscure funtion of the thyroid gland.

The above clinical contributions awakened a new interest in the study of the thyroid by animal experimentation, which had been carried on intermittently ever since the early thirties [9] of the last century, but with indefinite and contradictory results.

As a result, Schiff,[10] in 1884, clearly showed that certain animals, notably cats and dogs, regularly succumb to complete removal of the thyroid gland except in isolated cases which were explained on the supposition that the thyroid function was then carried on by aberrant or accessory thyroids.

In consequence of the dire effects which were thus noticed experimentally as well as clinically after complete thyroidectomy, it became a surgical mandate that part of the organ should be spared in goiter operations. This precept, which was fathered by Kocher,[11] has prevailed up to the present time and its practice accounts for the relative infrequency of postoperative tetany and cachexia strumipriva.

In the results of animal experimentation a perplexing inconsistency prevailed. Whereas total thyroidectomy in dogs, cats, and carnivora in general, was regularly followed by fatal tetany, in contrast to these animals, rabbits and other herbivora regularly survived the operation with no evidence of tetany, but with the development of the slower cachexia strumipriva.

The peculiar difference in the reactions of these two classes of animals to the removal of the thyroid gland was the crux which for a long time defied explanation and prevented further progress. Its ultimate solution, however, furnished the clew which resulted in rapid advances leading up to our present knowledge of the subject. The credit for this all-important step is due to Gley [12] who in 1891 called attention to the existence in the rabbit of two bodies entirely separated from the thyroid, the external parathyroids. He demonstrated that in this animal the removal of these together with the thyroid produced the same effects as complete thyroidectomy in other animals. His conclusions may be summarized as follows:

1. The removal of the thyroid alone (in the rabbit or dog), leaving the two external parathyroids, causes no tetany.

2. The removal of the two external parathyroids in the same species of animals, also causes no tetany.

3. The removal of the thyroid and the two parathyroids, at the same time or in two stages, results in tetany.

He explained incorrectly the negative effect of removing the thyroid alone (1, supra) by the assumption that the parathryoids which were left acted vicariously for the thryoid. Moreover, since he did not recognize the existence of the internal parathyroids, the negative results following removal of the two external ones suggested to him nothing significant.

Attention should be called to the fact that Sandstroem [13] in 1880, eleven years before Gley's contribution, had recognized the parathyroids in man, and had described their gross anatomy and histology minutely and accurately. Apparently little notice was taken of his report, and certainly it failed to stimulate scientific research. However, the name "glandulæ parathyroideæ" which he applied to the organs, has been generally adopted.

While a new theory was suggested by Moussu,[14] to the effect that the simultaneous ablation of the thyroid and parathyroids might possibly suppress two functions instead of one, the first practical step towards ascribing to the parathyroids an independent potency resulted from the work of Vassale and Generali [15] which was published in 1896. They demonstrated that the removal of the four parathyroids, the thyroid being preserved, led to fatal tetany; while no tetany resulted from the removal of the thyroid if the parathyroids were left. These conclusions were based upon the following striking experiments:

Ten cats; total parathyroidectomy; nine dead before 11th day. In all there were characteristic symptoms of tetany.

Nine dogs; total parathyroidectomy; all dead before the 9th day. In these animals the symptoms were analogous to those of complete thyro-parathyroidectomy. Every effort was made to exclude complications, such as injuries to nerves or to the thyroid as possible causes of the fatal results.

It has been urged by numerous experimenters, among whom are Biedl,[16] Walbaum,[17] Vassale and Generali, that the intensity of tetany parathyreopriva stands roughly in inverse ratio to the number of healthy parathyroids retained by the animal. Thus,

in a cat the removal of three parathyroids has been said to result generally in fatal tetany; of two, in lighter tetany; of one, in no tetany. But this rule is certainly far from absolute, for sometimes the presence of one parathyroid is sufficient to prevent the symptoms of tetany, while in other cases, two of the organs are necessary (Erdheim). The difficulty of formulating any exact deductions in regard to this phase of the subject is further increased by the fact that besides frequent variations in animals of the same species, there is a constant and marked difference in the reaction of different species to partial or complete parathyroidectomy, in respect to the rapidity of the onset and the intensity of the symptoms.

In 1903, Jeandelize, in an exhaustive treatise, reviewed and amplified the whole subject. The following summary from his work is a fair indication of the general attitude at that date.

1. The thyroid and parathyroids are different organs.

2. The results of ablation of the two are not the same.

3. Physiologically, the two organs are dependent upon one another, yet neither can assume the functions of both.

In elaborating the effects of ablation of these organs he calls attention to the fact that thyroidectomy alone does not cause the grave troubles of parathyroidectomy, but instead, especially in young animals, gives rise to troubles of nutrition. The animals remain undersized, their behavior is altered and sluggish, the skin becomes thick and edematous, and the hair becomes coarse. The onset of the change is less than a month after the operation.

On the other hand, he states, parathyroidectomy produces a more rapid onset of symptoms, which are briefly, fibrillary twitchings, tremors, local or general contractions (tonic or clonic), convulsions, dyspnœa, tachycardia, ptyalism, thirst, vomiting, diarrhœa, general weakness and prostration.

He therefore concludes that as a result of insufficiency of the thyroid there occur nutritional disturbances, whereas insufficiency of the parathyroid produces acute convulsive troubles. This, he says, is proved in several species of animals and is probably true for all vertebrates.

In consequence, it was assumed that operative myxedema, which is a nutritional disturbance, is due to removal of the thyroid, and tetany, which is a convulsive trouble, to removal of the parathyroids. Under such an assumption these two con-

ditions necessarily came to be regarded as radically different, a transition from one to the other being out of the question.

Erdheim has recently by clinical and experimental observations further elaborated the evidence of the potentiality of the parathyroids. After partial or total destruction of the parathyroids in rats, with the minimum of injury to the thyroid, he studied the symptom complex of the resulting tetany which occurred in all the cases of total parathyroidectomy. In the animals presenting tetany, by systematic serial microscopic sections of all the organs of the neck, he demonstrated the presence of the thyroid and absence of parathyroid, and thus established the fact that the lesion in every case was purely parathyreopriva.

Although individual differences were marked in his animals, tetany began, as a rule, several hours after operation, and reached its height usually in the first twenty-four hours in the form of epileptiform convulsions. The condition then passed into a chronic state. In the study of the symptom complex due to parathyroidectomy exclusively, besides demonstrating the regular occurrence of a typical tetany, Erdheim also verified the occurrence of regular nutritive changes, notably very excessive growth of the lower incisors. But the association with tetany of some trophic disturbances resembling those observed in cachexia strumipriva was not regarded as a justification for the conclusion that the two conditions are of identical origin.

Erdheim's studies of three cases of human tetany are remarkably significant. In each a partial thyroidectomy was performed for goiter. Unquestionably tetany developed shortly after the operation and death followed on the 131st, 5th, and 17th days. Very complete serial microscopic sections of the neck organs showed in each case the presence of considerable well preserved thyroid tissue, whereas in the first case none of the four usual parathyroids were found, and only two very small accessory parathyroids which lay in the thymus; in the second case only one parathyroid was recognizable, and that was practically entirely necrotic; in the third case not one of the regular four, nor even an accessory organ was found.

A review of all cases of tetany which have been reported as occurring after strumectomy would prove unfruitful. Only a small number are of practical interest in this connection, namely, partial thyroidectomies which permit definite conclusions as to

the involvement of the parathyroids in the extirpation. Pineles [18] compiled thirteen cases of this kind. Of these, there were six cases of extirpation of both lateral lobes, four cases of preservation of the upper portion of one lateral lobe, three cases of extirpation of a lateral lobe with the isthmus. As a result he pointed out that tetany follows partial thyroidectomy most frequently in those cases where extirpation of, or injury to, the parathyroids is most likely to occur; and consequently that tetany is most likely to follow those cases in which only the isthmus or upper part of a lateral lobe is left.

It seems then to have been proven by a long series of careful experiments, strengthened recently by the significant findings of Erdheim and Pineles in man, that tetany following goiter operations is due to the removal of the parathyroid glandules. Nevertheless, this attributes such marked potency to these little organs that, not unnaturally, there are still some observers who are skeptical as to the truth of the assumption, and among them are competent men who have weighed carefully all sides of the question. The explanation of this divergence of opinion lies in the fact that besides such apparently conclusive results as those described above, there have been numerous other investigations, the outcomes of which have not been uniform or positive. For example, even recently, Vincent and Jolly [19] have found that "removal of all four parathyroids was not necessarily fatal," and they "were unable to confirm some other statements which are very commonly accepted" on this subject. Further, Vincent wrote that "the question of the extreme importance of the parathyroids can not yet be considered as settled." Moreover, Caro,[20] although familiar with the extensive work of Pineles, has quite recently expressed the opinion that there is no reason for abandoning the former interpretation that tetany is an acute manifestation of the loss of thyroid (not parathyroid) substance. Animal experimentation has failed to convince him of the importance of the parathyroids. He states, moreover, that in goiter cases, the parathyroids are sometimes found to consist simply of atrophic and barely distinguishable lamellæ closely applied to the capsule, and he arrives at the conclusion that in Erdheim's three cases the dependence of the tetany upon the suppression of the parathyroids is by no means proven. However, it is fair to state that almost all observers at the present time regard tetany

following goiter operations as the direct result of the absence of the parathyroid function.

CASES OF TETANY PARATHYREOPRIVA, FOLLOWING PARTIAL THYROIDECTOMY, COLLECTED BY PINELES,[18] WITH LATER ADDITIONS.

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Reichel, (2 cases) Münch. med. Woch., 1905, p. 2012.
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ANATOMY OF THE PARATHYROID BODIES IN THE HUMAN SUBJECT.*

In man parathyroid bodies are constantly present; the number varies. Exact enumeration in an individual case is difficult for two reasons; first, their small size and variable position render it an easy matter to overlook one or more of the bodies; second, various tissues may be mistaken for a parathyroid, especially lymph nodes, hæmolymph nodes, accessory thyroids, thymus rests, and fat. Microscopic examination alone can exclude these tissues.

Berkeley,[21] as a result of about one hundred and twenty-five autopsies, concluded "that while the number four seems

* For technique of dissection cf. Berkeley[21] or Petersen.[23]

to satisfy the demands of anatomical symmetry, this number is often diminished by one or more " and occasionally increased. He apparently found on an average about two and a half parathyroids per person. Most observers have reported smaller averages, but Verebely [22] found four parathyroids 108 times in 138 autopsies. In our own dissections,† the last sixteen resulted in an average of 2.9 per person. In all of these one-half of every suspected tissue was removed and examined microscopically. The other half was left in situ for further reference; a lettered drawing of each specimen facilitated identification of the sections.

The occurrence of the glands in pairs may properly be considered the typical arrangement, a superior and an inferior body being present on each side. Judging from our own dissections and the descriptions of Verebely, Thompson [24] and earlier writers, the following seem to be the most frequent situations, and correspond closely to the drawing (Fig. VI).

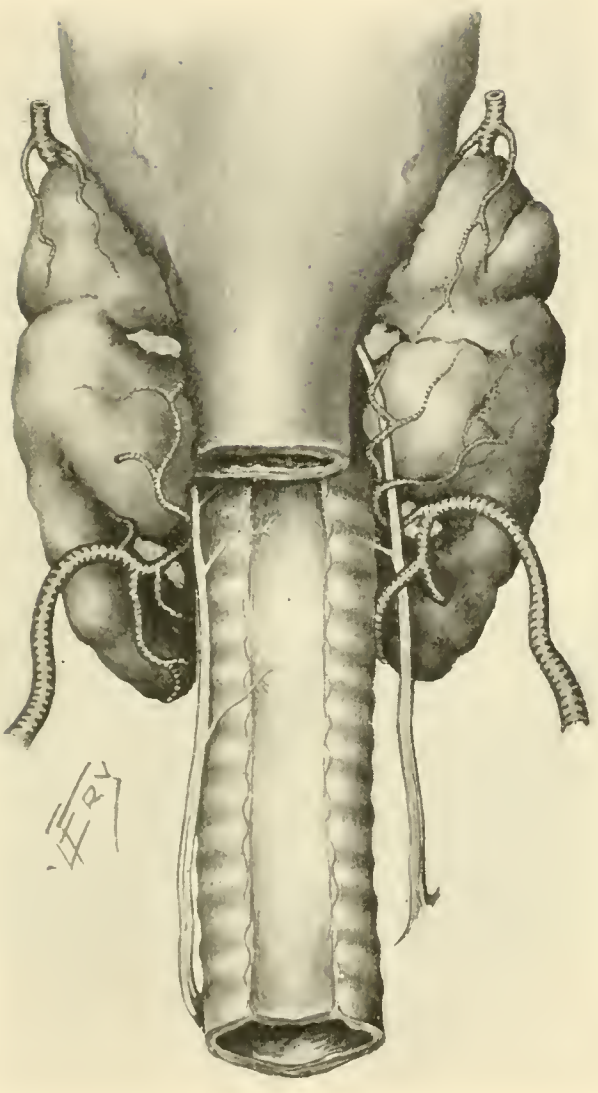
The superior, the more constant in position, lies close to the thyroid in the middle third of its posterior border, approximately on the level of the lower border of the cricoid cartilage (Welsh [5]). It lies in a plane posterior and external to the terminal branches of the inferior thyroid artery and recurrent laryngeal nerve. On the left side the gland is frequently further posterior than on the right.

The inferior, often intimately associated with the thymus (Verebely), lies at or below the inferior pole of the thyroid or on the posterior aspect of the lower third, in which case it is frequently found anterior to the recurrent laryngeal nerve and inferior thyroid artery, close to the thyroid gland at the entrance of the lower twigs of the artery.

Variations from these anatomical positions are frequent. The most striking which we have found was the presence of a large parathyroid on the anterior surface of the isthmus. As common variations in position may be mentioned the tip of the lateral lobe of the thyroid or even above this; anywhere on or

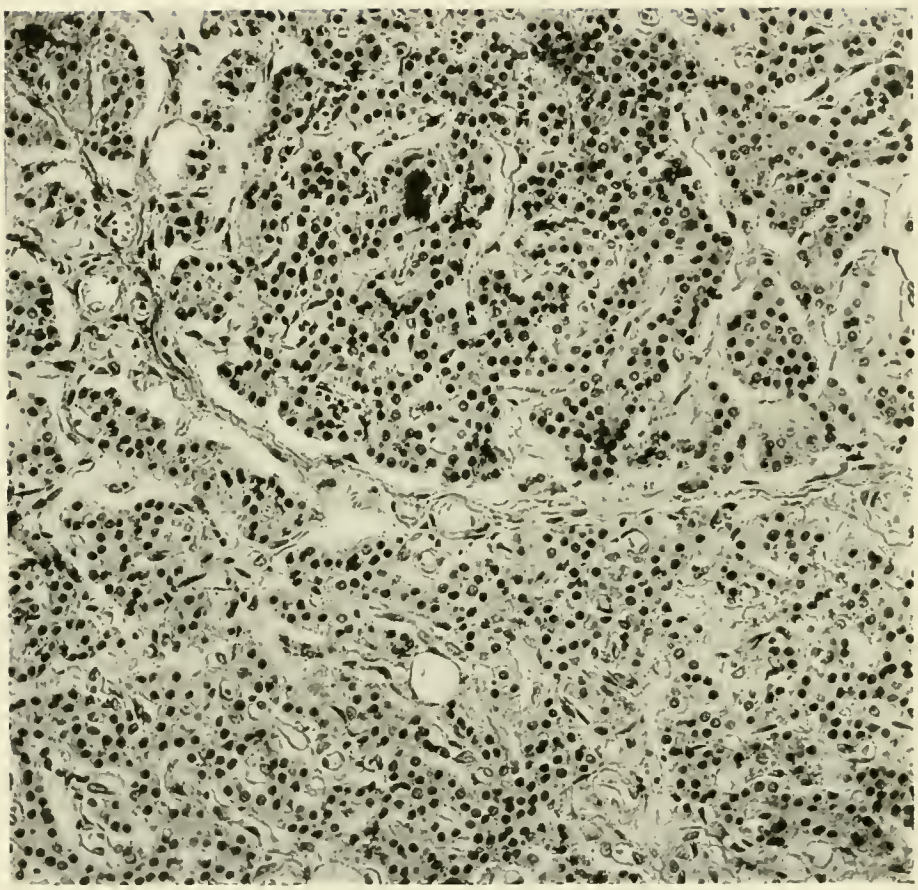
† These were done with the aid of G. C. Whitney, of the Third Year Class of the College of Physicians and Surgeons.

Fig. VI.



The parathyroid bodies, showing situations in which they are sometimes found.

Fig. VIII.

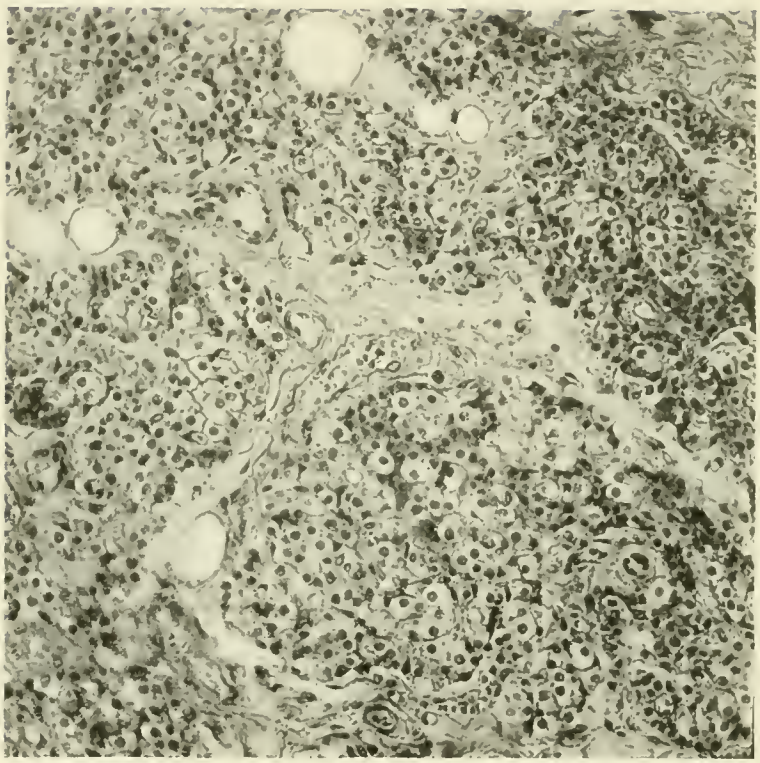


Distribution of cells in strands and groups. Colloid is present in several places. A.

Fig. IX.

Showing an acinus with lumen.

Fig. X.



Principal cells.

near the posterior border. These sites, however, do not limit the possibilities.

Accessory organs, that is, small accumulations of characteristic parathyroid cells, have been found not infrequently below the thyroid, especially within the thymus.*

While in most cases the glands lie embedded in fat outside of the thyroid, the position of one or more may be beneath its capsule, but only very rarely embedded in its substance (Verebely). Each parathyroid is completely invested with a thin fibrous capsule under which a fine anastomosis can be seen. The size of the organ varies from about 3 mm. to 15 mm., the average being about 6 x 4 x 2 mm. (Berkeley). The bodies are usually somewhat flattened, and may be of various shapes, but especially round, oval, or reniform. Occasionally a parathyroid is subdivided into two distinct parts. The color is a brown red or a reddish yellow. Often a glandule of regular outline presents a relatively large segment of fat. This is said to occur most often in advanced age.

The blood supply of the gland is derived from branches of the superior and inferior thyroid arteries, particularly the former.

Histologically (Figs. VIII–XII) the organ consists of a mass of cells invested with a thin fibrous capsule from which occasional irregular processes reach inward. The gland has a reticular stroma, and is as a rule strikingly vascular, presenting numerous large capillaries. Frequently fat is present, both as an infiltration of the stroma and as a cellular metamorphosis.[26] The amount is subject to very wide differences and to this is largely due the variable color of the gland. Especially in advanced life a considerable part of the gland may be replaced by fat. The distribution of the cells varies greatly. They may form an extensive cell mass with only occasional interruptions by vessels and fibrous strands, or they may be broken up by vessels and connective tissue so as to form clusters of lobules or net-like trabeculæ. Occasionally there is an alveolar group-

* They have also recently been described as occurring within the thyroid (Getzowa[25]).

ing of cuboidal or somewhat cylindrical cells with basal nuclei. These at times surround a lumen filled with colloid, which is said by Richardson [27] to be retrograde or degenerative material, and not a higher stage of glandular development. Intracellular and intercellular accumulations of colloid also occasionally occur, while glycogen has been demonstrated as a cell inclusion (Petersen).

The cell grouping rarely comprises one alone of the above structural types; as a rule there is a combination of the varieties, the divergencies presented by individual glands in this respect being very wide. The cells themselves are mostly polygonal, sometimes round or cuboidal. They are classified by Welsh [5] as of two distinct types:

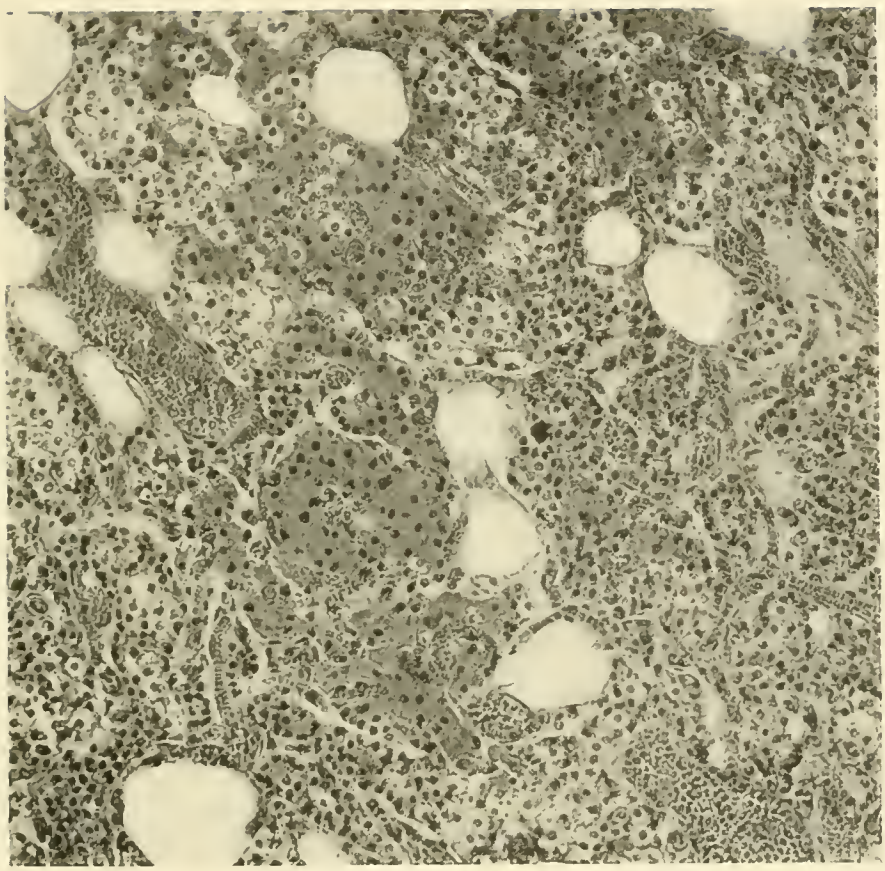
Type I. "Principal cells." These are by far the more numerous. The cell body is relatively small and is either feebly stained with basic aniline dyes, or is clear and colorless. The cells then seemingly consist only of nucleus and membrane which takes a deep eosin stain. We have noted that some of the cells which belong to this group sometimes present an irregular stained peripheral zone and a clear cytoplasm immediately around the nucleus. The variations in the relative width of the clear and the stained zones suggest that under certain conditions the cytoplasm of the clear cells takes on a stain which acts first near the periphery and then progressively toward the nucleus until the whole cell body may be stained.* The nucleus with open chromatin network is large, pale, often ovoid, and frequently, eccentrically situated. The distribution of these cells conforms to the general description already given.

Type II. "Oxyphile cells." These have a relatively large, finely granular body, the granules of which stain deeply with eosin. The nucleus with closely arranged chromatin is small, and round, and takes a deep stain. Compact masses of these cells frequently occur, especially immediately beneath the capsule. They are also distributed as anastomosing columns and as single cells or small groups scattered among the principal cells; lastly, in rare cases, acini with colloid are met with.

Petersen [23] adds a third type. His Types I and III are respectively the same as Types I and II of Welsh. He describes Type II as not characteristic. The cells are smaller than in I; there is no sharp boundary to the cells, of which the granular protoplasmic body stains deeply with eosin; in places

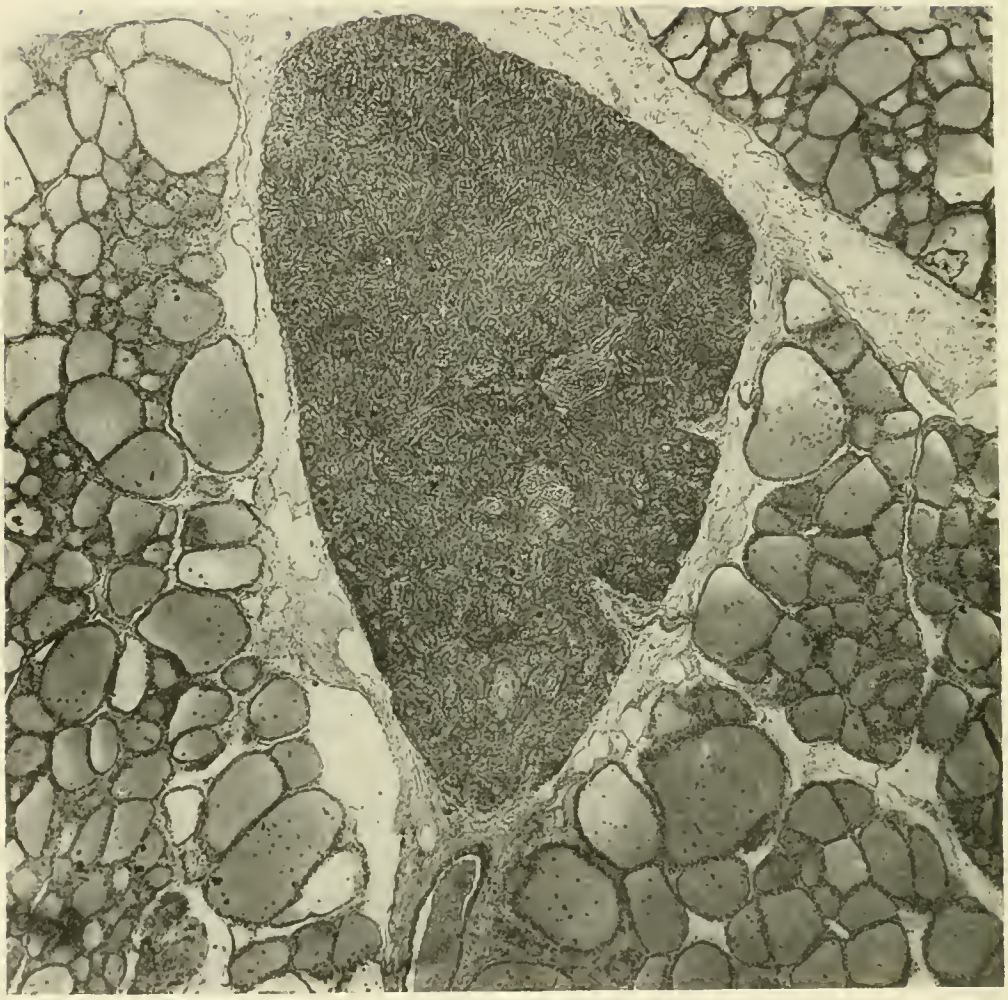
* Since the above was written, Getzowa has reported similar findings and has gone so far as to subdivide the group into "wasserhelle" or clear, and "rosarote" or pink cells.

Fig. XI.



Masses of oxyphile cells.

Fig. XII.

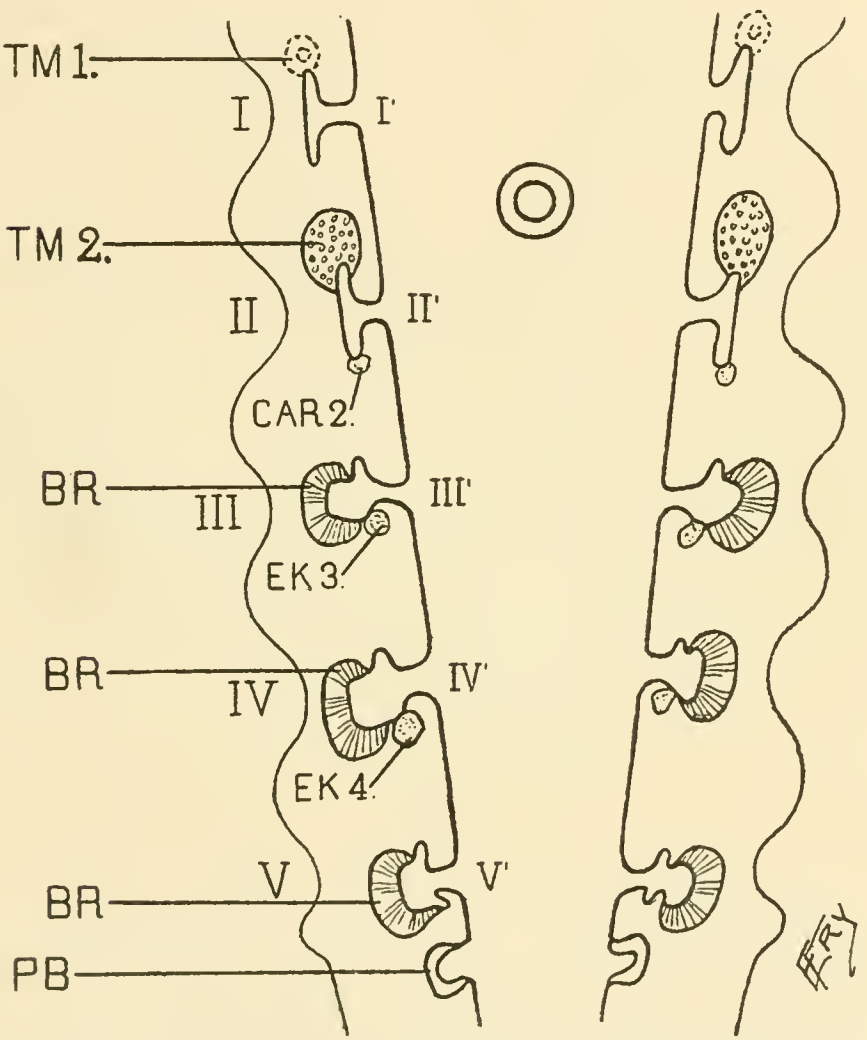


Parathyroid of a dog.

the cells are so small that nothing is seen but a complex of deeply stained nuclei. He states that all possible intervening forms occur between Types I and II, and suggests that the organ is a glandular one, and that Type I represents the functionating condition.

In studying parathyroids microscopically, the three varieties of cells can easily be recognized. Further, careful exam-

Fig. XIII.



Diagramatic scheme of branchial clefts from Anura. (Modified from Maurer.)

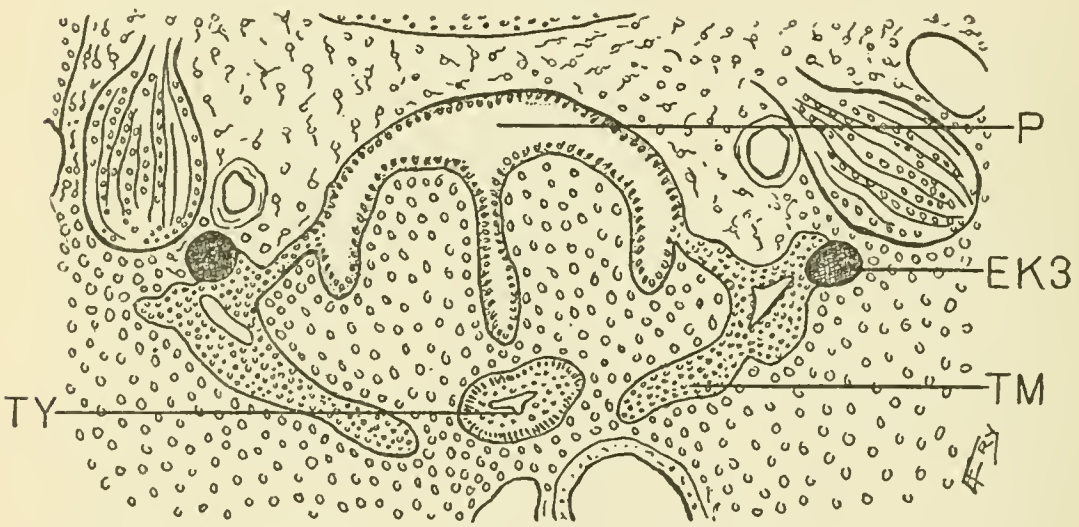
ination enables the observer to trace the cells in some glands from the clear ones of Type I through the above described granular condition to the small granular cells of Type II of Petersen. With more difficulty, gradations also may be traced

from the latter to the large granular cells (Type II, Welsh; Type III, Petersen), where these occur singly or in small groups; but the line of demarcation at the edge of the large groups is sharply drawn. Following the analogy of the salivary and other glands the question naturally suggests itself as to whether the granular cells are not the functionating and the clear cells the resting condition of the cells.†

EMBRYOLOGY.

It is necessary to touch briefly on the embryology of the parathyroids in order to establish their developmental independence of the thyroid.

FIG. XIV.



Transverse section of embryo of echidna, level of third branchial cleft. (Modified from Maurer.)

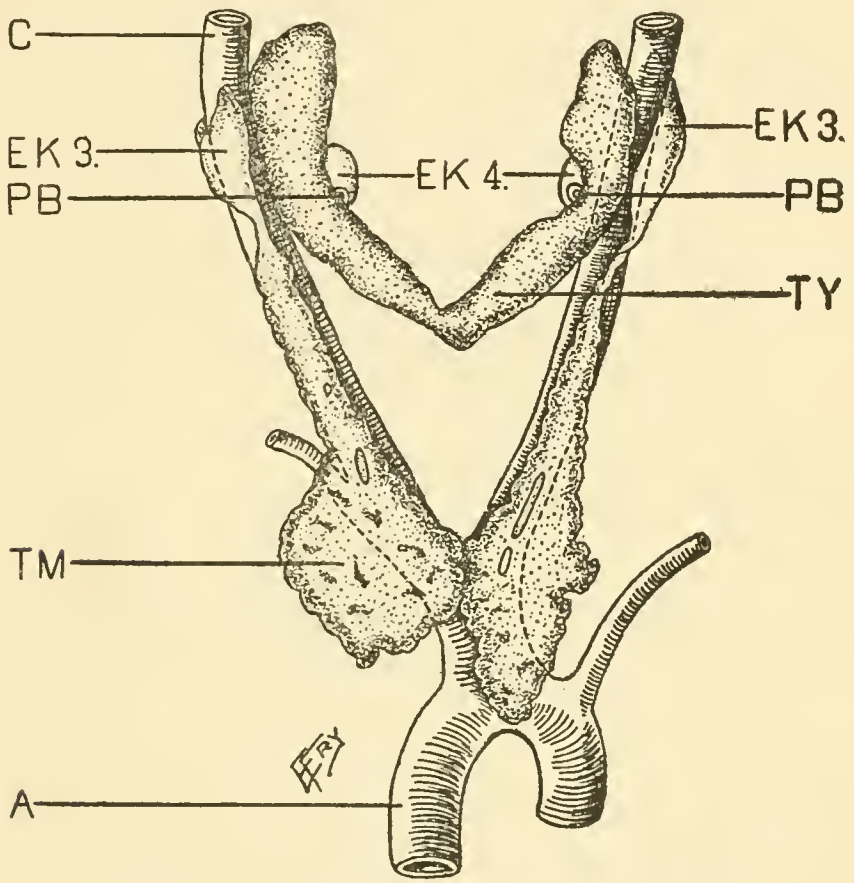
The parathyroids or "epithelial bodies" (Kohn[28]) are branchial cleft derivatives. In man and most mammals they develop from the third and fourth branchial clefts of each side as masses of compact epithelial cells which are in no way connected with the thyroid (Fig. XIV). Two on each side is the usual arrangement, though anomalies are not infrequent.

The third pharyngeal pouch with its derivatives, the thymus and the parathyroid body, becomes separated from the

† Getzowa[25] has recently expressed a similar view.

pharynx. This parathyroid body later comes into relation with the thyroid from the side and forms the inferior parathyroid or outer "epithelial body" (Kohn) (Figs. XV and XVI, EK 3). When the fourth pouch becomes separated, its derivatives, the parathyroid, thymus, and post-branchial body, are primarily connected. The post-branchial body and the superior parathyroid or " inner " epithelial body (Fig. XV and

Fig. XV.



Embryo of rabbit, 16 m.m. long. (Modified from Verdun.)

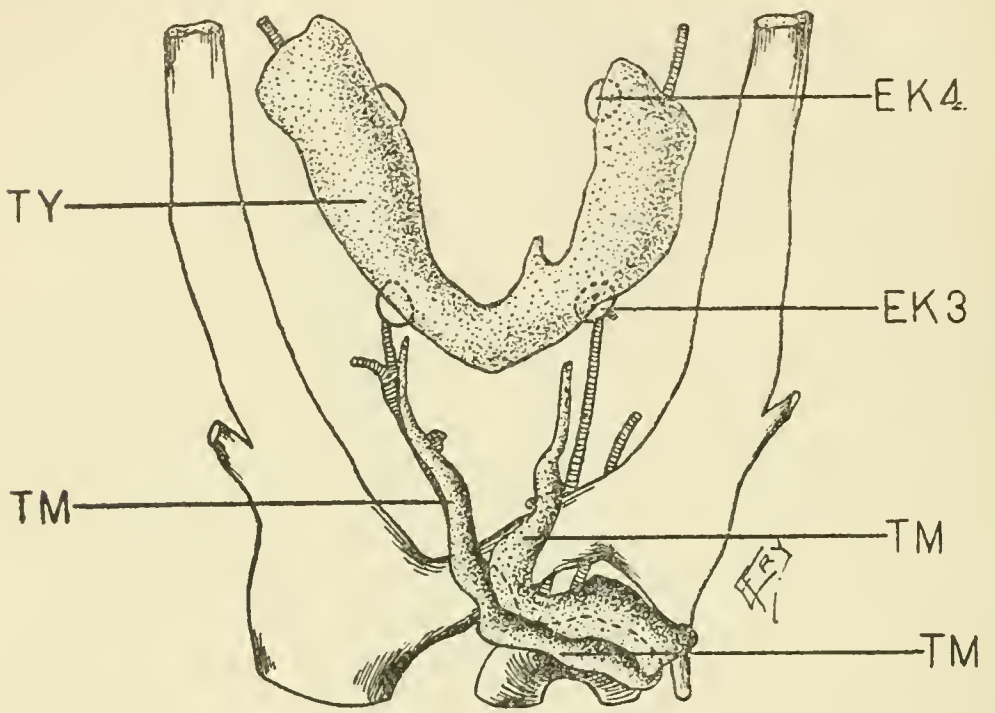
XVI, Ek 4) become annexed to the thyroid only secondarily in the course of development. There is no proof of the assumption that the parathyroids are embryonal thyroid tissue and that they may under certain conditions develop into the mature tissue of that gland. The relation of these bodies to the thyroid must, on the basis of our present knowledge, be regarded as purely topographical.*

* Sophia Getzowa in a very elaborate article has recently advanced

PHYSIOLOGICAL AND PATHOLOGICAL CONSIDERATIONS.

If we accept the view that the parathyroids have a function in part or altogether independent of the thyroid, there are certain hypotheses and experimental results which from a physiological standpoint are suggestive and offer a basis for further investigation.

FIG. XVI.



Human embryo 29 m.m. long. (Modified from Verdun.)

TY. Thyroid.	I-V Branchial clefts, outer aspect.
TM. Thymus.	I'-V' Branchial clefts, inner aspects.
Car 2 Carotid gland.	P. Pharnyx.
EK 3 Parathyroid of third cleft.	A. Aorta.
EK 4 Parathyroid of fourth cleft.	C. Carotid.
PB. Post branchial body.	BR. Branchial rests.

The hypothesis has been advanced by MacCallum,[29] Frommer,[30] Lundborg,[31] and others, that the parathyroids have an antitoxic action, the suppression of which results in the tetany reaction. By this hypothesis tetany parathyreopriva would be

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the hypothesis that there may be an independent third parathyroid developed from the fifth branchial cleft. In this way she would explain the occasional occurrence of parathyroid tissue within the thyroid gland in cases in which the extrathyroidal superior parathyroids are also present.

explained as an auto-intoxication. In support of this view is the fact brought out by MacCallum, that the disease in animals is temporarily relieved by bleeding and injection of salt solution into the veins; this, he thought, demonstrated the presence of a circulating toxin. The transmission of tetany to a healthy animal by transfusion of blood from one affected with the disease, although claimed by some as possible, can not be accepted as proved.

If the above hypothesis is accepted, and it seems the most plausible one yet advanced, it may fairly be assumed that whereas the thyroid secretes a substance which is necessary for metabolism, the chief function of the parathyroid is to prevent the action of certain toxic substances regularly present in the circulation.

Attempts to ascribe the etiology of all forms of tetany and even of certain allied diseases, as paralysis agitans, to an imperfect functional activity of the parathyroid glands, have not yet been successful. Nevertheless, Pineles [32] assumes the existence of a common etiology for all forms of tetany. He inclines to the belief that further research will trace the unopposed action of the tetanic toxin in all forms of tetany to a depressed functional state of the parathyroids. Chvostek [33] also expresses the view that all varieties of tetany are dependent upon the parathyroid bodies. His observations of tetany, apart from that following goiter operations, led him to believe that the essential feature in the etiology is a functional disturbance of the parathyroid glands so that they are unable to adapt themselves to various changes. It is due to this susceptible condition, he thinks, that menstruation, pregnancy, infectious diseases, etc., are prone to produce the tetany reaction.

The variety of food and the state of fullness or emptiness of the intestinal tract are said to have but little influence on the course of tetany (MacCallum).[34] Whether the iodin contained in the organ plays an important role is not known.

In regard to the nervous phenomena of tetany no conclusive explanation has as yet been offered.

Symptoms.—According to v. Frankl Hochwart,[35] with

whose descriptions of the disease the following account conforms, tetany parathyreopriva is characterized by certain very striking symptoms which render it practically unmistakable. The most conspicuous of these are intermittent tonic spasms of the voluntary muscles, those of the extremities being most affected. A salient feature is the exclusive involvement of the flexor groups of muscles. Intercurrent contractures of the facial muscles are relatively rare, and the muscles of the chest, back and abdomen participate in exceptional cases only. The tetanic spasms are usually preceded by certain prodromata which persist for a variable period before the onset of the attack. These include headache, sensations of weakness or prostration, more or less rigidity of the limbs, radiating pains and clonic twitchings. The contractions usually begin in the hands, and subsequently involve the feet; less often the feet are affected coincidently or independently. The spasms are almost always symmetrical and bilateral. As a rule, two or more of the fingers are flexed and the thumbs are forcibly adducted, sometimes tightly clasped by the contracting digits. In fifty per cent. of the cases, the wrist also becomes flexed, while flexion of the forearm with adduction of the arm to the trunk occurs infrequently. Exceptionally, the fingers are held wide apart, the terminal phalanges alone being flexed. The feet, when involved, take the position of pes equinus or equinovarus, as a result of contraction of the muscles of the calf. In the contractions of tetany, the affected muscles become very hard to the touch and oppose a powerful resistance to attempts at passive relaxation. Should this prove successful the tetanic attitude is at once resumed when the traction diminishes. Fibrillary twitchings are sometimes visible in the contracted muscles. The duration of an attack may not exceed a few minutes; or the attack may last for a number of hours; but it rarely persists as long as forty-eight hours. The termination of a tetanic spasm is frequently preceded by symptoms resembling those observed at the onset.

While there may be a free interval of days or weeks between the attacks, unfortunately this is far from being the rule.

There are generally several attacks in the course of the day, whereas the patient's rest at night is unbroken. In the severest cases one attack follows another with alarming rapidity.

Trousseau assumes three distinct degrees of tetany based upon the distribution of the spasms: first, a mild form, affecting the peripheral muscles only; some of these attacks may even be limited to the hands: second, a moderate form, with involvement of the facial, abdominal and trunk muscles: third, a severe form, extending to the involuntary muscles.

Besides the attacks of spasms there are other manifestations of the disease. Certain disturbances of sensation are regularly present, especially pain, which is a constant concomitant of the spasms. Hyperesthesia, paresthesia, or anæsthesia may also be noted. Temporary redness and edema are not infrequently observed over the joints. Trophic and secretory anomalies, such as sweating, loss of hair, and changes in the nails, are not very uncommon.

Of particular significance as bearing on the diagnosis are the tests of Chvostek, Trousseau, and Erb. In two-thirds of all cases of tetany it is possible to demonstrate Trousseau's phenomenon. The symptom consists in the occurrence of a tetanic spasm in a limb as the result of compression of its main vessels and nerve trunks. By the animal experiments of Frankl Hochwart and Kashida, this phenomenon has been shown to depend upon stimulation of the nerves.

Chvostek pointed out the facial phenomenon which can be elicited in tetanic patients by gently tapping over the area of distribution of the facial nerve. The resulting short twitchings are known as Chvostek's symptom, which is especially valuable by reason of the simple technique required for its demonstration.

Erb called attention to the fact that electric hyperexcitability of the motor nerves is regularly present in these cases. There is a marked increase of galvanic irritability, especially in the ulnar nerves; whereas an increased reaction to the faradic current is far less constant. The value of the two tests, dependent upon stretching the nerves of the

brachial plexus and the sciatic nerve, which were so striking in our case, can not be estimated properly until repeated trials have been made in further cases.

The tendon reflexes are normal or increased. A certain number of cases, too numerous to be interpreted as an accidental coincidence, present a combination of tetany with typical epileptic seizures. These symptoms have sometimes been observed after thyroidectomy in individuals previously free from nervous symptoms; and a possible connection between epilepsy and tetany has accordingly been suggested. Certain authors also include among the symptoms of tetany the hysterical attacks which are ocasionally present (cf. Frankl Hochwart).

The course of tetany following thyroidectomy has been divided by Frankl Hochwart into three classes: first, cases characterized by onset soon after operation, severe course, and fatal outcome; second, cases in which the symptoms appear soon after the operation but subside after a variable time and are followed by recovery; third, cases in which the patients live and symptoms of myxedema become associated in variable degree with those of tetany.

Diagnosis.—In regard to the diagnosis of tetany, Frankl Hochwart states that it is a simple matter and that there is only one condition, namely, hysteria, which may give rise to symptoms that are strikingly suggestive of those of tetany. But, he says, it will not do on that account to designate tetany or certain of its varieties as a manifestation of hysteria, for there are many features of tetany which can scarcely have anything in common with hysteria. Although he believes imitation of tetany to be uncommon, one can not overlook the possibility of imitation of the symptoms particularly after the tetany has run its course. Such was Minor's [36] explanation of a case observed by him.

Tetany, according to Frankl Hochwart, is at once suggested in the case of individuals who have recently undergone an extirpation of the thyroid gland. He emphasizes particularly the importance of Trousseau's sign as a differentiating test. It is unquestionable that responses can be obtained by

pressure in hysteria and other conditions, which may be readily mistaken for Trousseau's sign (Curschmann[37]). But in a given case, Frankl Hochwart says, the differential diagnosis should be based upon the sudden appearance of spasms as the result of pressure in hysteria, whereas in tetany tonic rigidity is very gradually induced by pressure. He goes so far as to say that in a considerable number of hysterical patients he never succeeded in producing anything akin to Trousseau's phenomenon.

The marked galvanic hyperexcitability of the motor nerves and especially of the ulnar nerves is an important feature for diagnosis. But whether its absence should be regarded as conclusive in ruling out the disease is questionable. Weiss[38] reported one case among thirteen cases of tetany examined by him, in which there was no hyperexcitability. Frankl Hochwart says that he observed a similar case but did not regard it as conclusive because it happened that the ulnar nerve was not tested in this particular patient. Recently, he says, a woman came under his observation who he knew had suffered for years from tetany strumipriva, and had generally presented a very marked galvanic hyperexcitability of the nerves. This time it was not distinctly increased and at best could be designated as rather "high."

Treatment.—Much experimental work has been done on this important phase of the subject. There is, however, considerable confliction in the results reported. This is not surprising since the course of the disease in animals is so irregular as to render it extremely difficult to estimate the effect of treatment. Even without treatment, some animals which present profound manifestations of tetany a few hours after operation, pass, after one or more such attacks, into a chronic condition and live for days, in contrast to others in which the first attack proves fatal.

Attention was naturally first directed to the administration by mouth of thyroid and parathyroid glands and their products. Hoffmann,[39] Levy-Dorn[40] and Westphal[41] and many others have reported improvement of the symptoms of

tetany in man after feeding thyroid gland or its derivatives. Most observers, however, disclaim any favorable results with exclusive thyroid therapy, and Loewenthal and Wiebrecht [42] ascribed the apparent effects of thyroid feeding to the admixture of parathyroids. Yet it does not appear to have been proven that either mixed thyroid and parathyroid or even pure parathyroid feeding can control the disease in animals. According to Biedl [16] (p. 321) "the sequellæ of parathyroidectomy cannot be prevented by parathyroid feeding." MacCallum [34] reported benefit as the result of intravenous injections in parathyroidectomized dogs of very large amounts of prepared parathyroids of dogs. Administered to animals in subcutaneous injections, thyroid gland derivatives have proved inefficient, whereas parathyroid products are said to have met with some success at the hands of Beebe,[43] and others. With the nucleo-proteid Beebe claims that amelioration or disappearance of the symptoms is almost constant.

Uncertainty prevails as to the effect of transplantation. Transplanted parathyroid tissue survived in the animal experiments of Cristiana,[44] and became atrophied after a variable time in the experience of Camus,[45] whereas Lusena [46] refers to cases in which the subcutaneous transplantation of parathyroid seemed to have a decidedly favorable effect.

Of the applicability of the above methods in man little has been demonstrated. Here the effects of treatment are difficult to estimate because of the impressionable character of the patients and the frequent modification of the disease by hysterical manifestations. Some successes with thyroid feeding have been reported, as stated above, and MacCallum,[47] Marinesco,[48] Lowenthal and Wiebrecht [42] and others have reported improvement following the administration of parathyroid material by mouth. Yet the results in animals apparently have demonstrated that in the treatment of tetany by parathyroid therapy, subcutaneous administration is the means which offers the best prospect of controlling the disease. Beebe's nucleo-proteid at present appears to be the most efficient product for this purpose.

There is no record before the present of attempts to establish a permanent cure in man by parathyroid transplantation.

Transplantation.—The important part which tissue transplantation now occupies in the experimental work which is being done in tetany, and its peculiar significance as a possible therapeutic agent in this disease warrants a brief review of the main principles of the subject.

Parenchymatous organs, in part or in entirety, seem to have been successfully transplanted in a number of cases between animals of the same species, and even between human beings. But the transplantation of such tissue from an animal to man or experimentally between animals of different species, has almost * uniformly failed, presumably by reason of some cytolytic property of the fluids of an animal towards tissues of another species. The implanted tissues certainly do not abide permanently, and temporary functional effects may fairly be assumed to result from absorption of the implanted tissue and its juices.

The behavior of individual glandular organs when transplanted is extremely variable. According to Payr,[50] those organs which have an internal secretion seem to be far better adapted to transplantation than those with an external secretion.

Of parenchymatous transplantation, that of the thyroid gland is by far the most important. The original experimental transplantations of this organ in animals were done by Schiff,[51] and the first attempt in man was made by Kocher in a case of cachexia strumipriva (1883). The functional results in both instances were transient only. It was tried by Bircher[52] and others for myxedema, but with similar results.

The first attempts which seem to have been successful in respect to the life and function of the transplanted thyroid tissue were those of v. Eiselsberg[53] and Cristiani.[54] But whether this functional activity is only temporary, as urged by Ender-

* Christiani[49] reported some success in the transplantation of thyroid tissue from one animal to another of a different kind.

len,[55] is still problematic. However, Payr [50] has recently reported striking and suggestive results in animals and in the human subject. He transplanted thyroid tissue from the mother into the spleen of a six year old child who was suffering from congenital myxedema. Marked improvement is said to have resulted, and to have persisted up to the time of publication eight and a half months after the operation.

Among other tissues of which successful transplantations in animals have been reported are the ovary, mammary gland, adrenal body, and kidney; in the human subject, besides the thyroid, the ovary may be mentioned.

Among Carrell's remarkable successes in transplantations of the kidney are some in which he demonstrated that the viability of the organ was preserved during an interval of two hours between its excision and its implantation. When an interval thus elapses it has been shown by Cristiani that the viability is best retained by preserving the tissue in serum from the same species of animal or in inactivated serum of an animal of another species; the ordinary salt solution proves toxic. Flexner found that this also applies in the case of pathological tissue.

As to the most favorable site for implantation, opinions differ. The main places to be considered are the subcutaneous tissue, extraperitoneal tissue, peritoneal cavity, omentum, and spleen. In determining the situation for election in a given case attention must be given to the freedom from serious danger which it offers and to its qualifications for supporting the life of the implanted tissue.

Looking now towards the possibility of parathyroid implantations, from general experience grafting between animals of different species would not appear promising; but for obvious reasons the question should be definitely settled on account of therapeutic possibilities. Between animals of the same species, on the other hand, some prospect of success seems offered. Payr mentions several cases in his experiments in which living parathyroid as well as thyroid tissue was found embedded in the spleen at a considerable interval after the

transplantation. Moreover, since his thyroid implantations were said to be functionally successful, by analogy one might reasonably look for similar results with the parathyroid. Finally, Lusena and Cristiani seem to have obtained some functional effects in pure parathyroid transplantations.

With the view of solving the therapeutic possibilities of parathyroid transplantation in man, experiments were undertaken to establish the following essential questions:

1. Can the parathyroid live if transplanted, first, between animals of different species, second, between animals of the same species?

2. If it lives, does it functionate; and, if so, is the function permanent?

In the first series, the rabbit was adopted as the donor, because of the accessibility and definiteness of the external parathyroids which were regularly employed. The dog was adopted as the recipient in both series because it seemed likely that the subsequent removal of the normal parathyroids would be relatively simple and certain. Experience showed that this choice was a mistake and that some other animal probably would have proved better.

The spleen was taken as the site for implantation because of Payr's successes and his claims in favor of it. He suggests that the spleen offers the most suitable combination of the two main factors necessary in tissue receiving an implantation, namely, high vascularity and richness in lymphatics.

The points of interest in my experiments were as follows: In one rabbit one external parathyroid was removed; the other was exposed and its size recorded; no tetany resulted. Eighteen days later the second external parathyroid had increased considerably in size. Similar enlargement has been noticed by others, and it has been suggested that it is in the nature of a compensation for the organ lost. In seven rabbits both external parathyroids were removed; there followed no tetany except in one animal which presented twitching of the head for about two days. In three rabbits complete thyro-parathyroidectomy was performed; in two, tetany developed with death in

thirty and forty hours; the third died on the ninth day, but no positive signs of tetany were noticed. In four dogs complete thyro-parathyroidectomy was performed. In all, tetany of variable intensity developed with death in two to sixteen days. In four dogs complete parathyroidectomy was done, leaving the thyroid. In three fatal tetany developed; in one, questionable tetany without death.

These results simply bear out the experience of many others in regard to the effect of removing the parathyroids. The tetany developed in the dogs in spite of the fact that in all except three of the cases implantations had been made.

Parathyroids were implanted into the spleen of twelve dogs, that is, the eight mentioned above and four others. In eight of these, sixteen rabbit parathyroid were used; in four, ten dog parathyroids. The technique of Payr was followed with some modifications. The implantations were made from eight to twenty-eight days prior to one of the above operations for removing the normal parathyroids, except in one case where the implantation and parathyroidectomy were done simultaneously.

CONCLUSIONS.

From the preceding considerations it is evident that the removal of all and possibly even of a part of the parathyroid bodies results in tetany, that the symptoms of this disease are striking, that the diagnosis is usually simple, and, finally, that efforts directed towards its cure have not as yet been proved to be successful.

In the case reported at the beginning of this paper, the diagnosis of tetany was based, in the absence of thorough electrical tests, first, upon the fact that the patient had never presented any hysterical or other nervous manifestations previous to the onset of the typical clinical features of tetany four days after an operation for goiter which thus supplied a direct anatomical basis for the disease: second, on the analysis of the symptoms, the most suggestive features being the frequent attacks of symmetrical and bilateral tonic contractures of hands and feet, the involvement of the flexor muscles exclusively, the

presence of Chvostek's and Trousseau's signs, the latter characterized by slow contractions accompanied and preceded by cramp-like pains, the additional demonstration of the mechanical excitability of the motor nerves by the stretching of the sciatic nerve and nerves of the brachial plexus; and, finally, the fact that coincidently with the typical spasms all of the above tests disappeared.

Assuming then that this was a case of true tetany, the explanation must be that at her former operation in Bern two parathyroids were removed with the left lobe of the thyroid. Since no symptoms occurred until after my operation this was undoubtedly the cause, presumably through the sacrifice of sufficient parathyroid tissue to upset the functional equilibrium, which must have been at that time very unstable as the result of the previous operation. It is not possible that both the remaining parathyroids were sacrificed, for in that case a fatal tetany would undoubtedly have resulted. Since no parathyroid could be found in the tissue removed, it is probable either that the lower and inferior one of the right side was crushed in the clamp which was placed across tissue in which this body sometimes lies, or that the blood supply of one or both of the parathyroids on this side was interfered with by the ligation of the inferior thyroid artery. The latter explanation was suggested to me recently by Dr. W. G. MacCallum.

In this case, although improvement and apparent cure resulted during the administration of Beebe's nucleo-proteid and after the subcutaneous implantation of human parathyroids, the fact can not be lost sight of that the improvement may have been due to a compensatory hypertrophy of the upper right parathyroid body which is supposed to have been left. Although it seems probable, on the basis of this case and the investigations of others, that by appropriate organotherapy the symptoms of tetany can be controlled at least temporarily during the administration, the question has not been definitely settled. Moreover, the effect of transplantation is still problematic. From animal to man it offers no prospect of success; and we are forced to admit that it is uncertain whether para-

thyroids transplanted between animals of the same species, even under the most favorable conditions, can functionate, even if they do survive. It is consequently equally questionable whether they can grow and functionate when transplanted from man to man. Although subcutaneous implantations seem warranted on account of their freedom from danger and the possibility that they were effective in the case under discussion, the obvious technical difficulties and dangers of implantation into such a place as the spleen, are so great as to forbid the attempt until success in animals has been thoroughly demonstrated.

Considering then the uncertain status of all proposed methods of treatment, the importance of prophylaxis is self-evident. In this connection it is significant that the frequency of the disease has markedly diminished since the adoption as routine practice of leaving part of the thyroid in goiter operations.

The practical side of this subject has been furthered by recent researches only in so far as it has been demonstrated that not merely sufficient thyroid must be left in order to prevent the occurrence of myxedema, but also that a definite part of the thyroid must be retained in order to ensure sufficient parathyroid tissue and thus guard against tetany. The truth of this statement is demonstrated by the case presented in this paper and by the cases of tetany following partial parathyroidectomy collected by Pineles and quoted above with later additions.

The operator must attempt to leave at least two of these bodies in situ, with blood supply unimpaired. When we consider how difficult it is to locate the parathyroids at autopsy on account of their small size and variable situation, it is evident that under the conditions which prevail in an operation, their recognition could not be depended upon and would prove a matter of chance. Therefore, in order to preserve the parathyroids, it is necessary to leave the posterior part of at least one lobe of the thyroid, in connection with which two of these bodies usually lie. Whether this is done by leaving one lobe

completely or in part, is a matter for individual choice in a given case; but in pursuing either course the thyroid vessels, especially the inferior, on this side should not be ligated. The practice of leaving the isthmus only is obviously a very dangerous procedure. In addition, to ensure still further immunity from tetany, even when one entire lobe or the posterior part of a lobe is left, certain precautions should be taken if the whole of the other lobe is removed. In the removal of this lobe the dissection of the thyroid gland should be carried as close as possible to the true capsule of the organ, and independent, small bits of tissue should be sought for in this situation, stripped from the thyroid, and left uninjured. Moreover, in ligating the inferior thyroid artery on this side care should be taken to avoid including in a ligature or clamp the inferior parathyroid which frequently lies in close relation to this vessel.

From the preceding review and discussion it is evident that numerous questions relating to the parathyroid bodies and tetany are still unsolved. Two important points, however, may be accepted as proved by the overwhelming evidence of experimental and clinical observations: first, that tetany following goiter operations is due to operative interference with the parathyroid bodies; and, second, the corollary of this, that in operative procedures parathyroids and their blood supply must be maintained inviolate.

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OBSERVATIONS UPON A FORM OF EXOPHTHALMIC GOITRE OCCURRING IN A DOG.

BY CARL EGGERS, M.D.,
AND
J. W. DRAPER MAURY, M.D.,
OF NEW YORK.

THE history of this case was briefly as follows:

The mother was an imported Irish terrier brought over on a cattle ship. She was badly treated during the trip and also for some time after her arrival in this country. At length she was picked up by a stable hand, who kept her in a rather cold, dark and damp stable. Her neck had always been noticeably full, but not remarkably so. Under the stableman's care, she revived and became bright and active. About eight months later, she gave birth to a litter of pups. These were sired by a thoroughbred Irish terrier. He also had been kept under poor hygienic conditions in the cellar of a saloon.

There were five pups. One, a female, was drowned at birth. Another died early from some unknown cause. About three weeks later, the remaining pups were all observed to have a swelling in the neck and they seemed to be weak in their hind quarters. Unfortunately no particular attention was paid to them until one died with symptoms that were noticeably like those of exophthalmic goitre. The two remaining pups were then seen by a member of the Surgical Research Laboratory staff. He noted that the thyroid gland was markedly enlarged; that the hind quarters of the dog were very weak; that the pulse was exceedingly rapid and that there was a very marked movement of the thoracic wall and indeed of the whole body due to the violent heart action. A very fine muscular tremor was quite marked.

One of the two remaining pups died before operation was decided upon, and the body unfortunately was destroyed before an autopsy could be performed. The last pup was then taken to the Laboratory and there presented the following symptoms:

A very marked swelling of the thyroid gland which was more prominent on the left side. It was elastic and throbbed synchronously with the pulse. The pup was extremely weak in the back and hind legs. When the photograph in the accompanying cut was taken, the animal was unable to stand and had to be supported as shown. There was very marked tremor. Little or no exophthalmos was present. The pulse had exaggerated force. It ran between 160 and 170 and was of high tension.

Upon the history, the presence of the tumor, the tremor, and the

tachycardia, a tentative diagnosis of exophthalmic goitre was made and operation decided upon.

The dog was given a dose of morphine hypodermically and when under its influence was anæsthetized with ether. The thyroid gland was exposed through a median incision. It was found to be enormously enlarged and to have an abnormally large vascular supply. The left lobe was larger than the right. The isthmus was ligated in two places and was carefully divided between ligatures. The gland was found to be well encapsulated and it shelled out easily. The parathyroids were not seen. The wound was washed out and closed with a continuous silk suture and dressed with a formalin pad. The pup re-acted well after the operation.

The next day an immediate improvement was noticeable in the animal's condition. The pulse rate had fallen to 120 and the impulse of the heart-beat against the chest wall had diminished very appreciably. Prior to operation it had been possible to count the heart beats by simply looking at the animal's body. After operation, this could no longer be done.

Four days after operation, the pulse had reached 90. There was no longer any impulse transmitted to the hand. The animal's general condition improved rapidly. He gained weight and all tremor disappeared. Weakness, however, persisted for some time, but at the end of two weeks, he was in a reasonably normal condition. The animal lived for six weeks after operation and died without giving any manifestation of a recurrence of the symptoms described.

Dr. MacCallum, of Baltimore, in speaking of this case, said:

"I should think it difficult to make a definite diagnosis of exophthalmic goitre in a dog, but I think the histological character of the goitre would furnish the best evidence of the nature of the condition. The literature is very meagre and I think any such case ought to be reported." Dr. F. C. Wood, of the Path. Dept., stated that this gland, a section of which is here shown, presented the usual morphology of exophthalmic goitre. His language is as follows:

"The microscopical examination of the thyroid tumor which you sent me some time ago, shows a growth of the type which we are accustomed to see in exophthalmic goitre in man."

Woods Hutchinson says: "I can quite readily imagine such a condition of affairs developing in the dog, as ordinary cystic and fibrous goitres are quite common in the species and generally give rise to few or no symptoms except those connected with their size. Similar conditions are also fairly common in horses and sometimes give rise to some difficulty, through pressure upon the trachea, and pneumogastric. I have also reported briefly a number of cases of cretinism occurring in puppies in goitrous regions, particularly in the Yakima and Puyalap valleys in Washington."

Wesley Mills, the well-known authority on dogs, writes from McGill University in reference to this case: "I have worked upon the effects of removal of the thyroids and parathyroids in dogs and I have seen a good many cases of ordinary chronic enlargement of the thyroid, but such an

FIG. 1.

Goitre in the neck of a dog.

FIG. 2.

Exophthalmic goitre in dog.

acute case as you have had the opportunity to study has not come to my notice. In all my study of the dog, I have been impressed by his resemblance to man, both physically and psychologically. The chronic enlargement of the thyroid always gave way in my experience to the treatment usually employed for human beings. I see no reason to doubt that your case was one of exophthalmic goitre."

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THE POSITIVE-PRESSURE METHOD OF ARTIFICIAL RESPIRATION

With a Practical Device for its Application in Thoracic Surgery, together with a Report of Transpleural Operations on Fourteen Dogs

By NATHAN W. GREEN, M. D.

ARTIFICIAL respiration may be of use in the fields of emergency-work, of medicine, and of operative surgery; in resuscitating the asphyxiated and drowned; in maintaining respiration while poisons are being eliminated from the system, as in opium-poisoning (1, 2), or ether in overdose; and in preventing the alarming symptoms incident to collapse of the lung during operative work (3).

Different methods of procedure in the surgery of the thoracic cavity have been attempted with the hope of warding off the undesirable phenomena incident to pneumothorax. Sencert, in some of his experiments, admitted the air gradually through a small pleural puncture. Tuffier and Hallion made a small opening down to the pleura, and then opened it with an incision large enough to admit only one finger (4). Others have used compresses to remedy the respiratory and cardiac disturbances (5). Others have opened into the lung only after an attempt to form adhesions had been made, either by the use of some chemical, such as zinc chloride, or by a suturing of the visceral to the parietal pleura, this being done while the two surfaces were approximated by the act of coughing (6). Latterly, research efforts in the line of thoracic intervention have been directed toward obtaining a free field of operation with a sufficient opening to admit the

hand, and yet without interfering seriously with the function of respiration or causing material collapse of the lung.

Opening one pleural cavity, in many instances, causes great mechanical impairment of the expansion of the other lung (7). This is the case frequently in dogs, where the mediastinal wall is delicate and very elastic; and in the goat, as Milton of Cairo has pointed out, in the one experiment which he performed. This is the case in young children also, where the mediastinal tissues are soft and yielding, and where the thoracic viscera play with extreme mobility (8). "Age is an important factor in the production of the bad symptoms of pneumothorax, and young children are especially susceptible to its disastrous effects" (9).

Many attempts have been made to overcome the results of suspended activity, both of the respiratory center and of the impaired respiratory mechanism. These have been by posture and passive movements which effect respiratory change of air, as in the method of Sylvester, Hall, Howard (10), Schöller, Djelitzius, and Ploman (40); by the direct insufflation of the lungs through a mask over the face, a tube in the nostril, or a canula directly introduced into the larnyx, as by Chaussier, and later by Depaul, Ribemont (11), Fell, and O'Dwyer; by tracheotomy, as is the common practice in physiological laboratories; or by the enveloping of the thorax or entire body, with the exception of head and neck, in an air-tight case or chamber from which the air has been partially withdrawn, as in the apparatus called "the spirophore," devised in 1876 by Woillez, for the closed chest (12), and later, quite independently, by Sauerbruch of Breslau, for the open chest (13).

Various forms of apparatus have been devised by Brauer and Petersen (14), Hans Meyer (for laboratory use), Doyen, Matas, and Sauerbruch. The sealed chamber of Sauerbruch has perhaps received the widest attention. Some of these are mentioned here because of their portability and convenience. The one devised by Matas consists of a cylinder which delivers a measured quantity of air to the lung. This may be regulated, and direct inspection of the lung in the open

chest may gauge the pressure, or a manometer may be placed in the circuit. It also had an aspirating-cylinder, but Matas now states that it was not useful, but caused harm by bringing about a collapse of the smaller bronchial tubes, which are not sufficiently cartilaginous and rigid to resist even moderate, slow aspiration. He found that "when inspiratory pressure on insufflation was equal to +10 to 14 mm. of mercury, the negative pressure or expiration was —20 to 24 mm., as gauged by the manometer." He further states that the evidence obtained from his first experiments on dogs promptly led to the abandonment of all expectation of ever utilizing the duplex method in practice.

The same principles have been elaborated in the Hans Meyer apparatus as in the duplex pump of Matas. This pump may be run by an electric motor or by water-power (15). It is very ingenious, and may be made fairly portable, but it has certain mechanical imperfections which render it difficult of satisfactory operation in duplex. The chief mechanical drawback is, that, owing to leakage past the piston-rings, it is impossible accurately to balance the outflow with the inflow of air. This being the case, it is necessary to insert two safety-valves when using the duplex method, one for preventing too much positive pressure and one to guard against too great negative pressure. This renders the apparatus slightly more complicated. If positive pressure only is used, the foregoing objection does not hold.

Doyen's double bellows are interesting, and they may be placed in the list of convenient and portable pumps (16). In the Brauer and Petersen apparatus the requisite pressure may be supplied, in case of emergency, by a cylinder of oxygen discharging through a rubber tube (17).

F. T. Murphy of Harvard has used in the laboratory an ingenious method similar to that of Brauer. He utilizes a continuous positive air-pressure, produced by water displacement, and gauged by a water manometer not exceeding 10 cm. Having connected this with the animal by a sort of mask fastened around the mouth and nose with surgeon's plaster, the lungs are kept dilated, and the animal effects its own interchange of air, as with the Brauer apparatus.

Many devices have been invented to convey the air under pressure into the lungs. A laryngeal canula has been used, a hood, a mask, or a sort of helmet enveloping the head or partially covering the face. Sauerbruch has tried incasing the head in a box under positive pressure, in his earlier experiments. F. T. Murphy has devised a sort of diver's helmet, made of galvanized iron, which is light, practical, and portable (18). The same method is in use in the latest apparatus of Professor Brauer. Tracheotomy tubes have also been used, in one form or another.

Laying aside the postural emergency methods, we find the subject of artificial respiration extending in two directions; one toward the production within the bronchial tree of an increased atmospheric pressure, and the other toward a production around the visceral pleura of a slightly diminished or negative pressure. Each of these divisions has its advantages, and almost equally its disadvantages.

Artificial respiration by means of increased pressure or insufflation has many things to be said, theoretically, in its disfavor. Among the most important is the fact that it inverts the normal physiological process, and causes changes in the circulatory system, which Sauerbruch tells us are not to be passed unnoticed. The method of incasing the body, and especially the thorax, in a negative pressure is best known through the observations of Sauerbruch, and has much in its favor. The most potent argument is, that it more nearly surrounds the opened thorax with the normal environment, and thus wards off more surely interference with the circulatory system. The method of Sauerbruch can best be understood by reference to his comprehensive article appearing in 1904 (13).

Brauer says that it is his opinion that after pneumothorax once exists there is no difference between Sauerbruch's method of rarefaction and his own of compression. Both procedures are then alike, the effect in each being due to difference of pressure on inner and outer lung surface. It seems to him the same whether the pressure difference is obtained by increase of inner pressure or lowering of the outer. In both cases it is the pressure acting on the inner surface which keeps

the lung dilated (19). He says the so-called negative pressure in the pleural cavity is not action of suction on the lung surface, as it is in the case of Sauerbruch's method with rarefied air. "Under normal conditions, the lung adheres to the inner surface of the thoracic cavity. It is the adhesion, the capillarity, of the pleural sac which maintains the lungs in its place. The so-called negative pressure becomes an actual factor only when air enters between the layers of pleura." Consequently, under normal conditions, the lung elasticity is overcome, not by pressure of air on the inner surface of the lung, but by the elasticity of the thoracic wall. The two factors — traction of the lung towards the inner side and traction of the thorax towards the outer side — are equal. It is consequently, under normal conditions, not an air-cushion which carries the lung, but it is a direct stretching of the lung tissue by the above-mentioned adhesion. These things should be well understood, for they are of great importance, says Brauer.

"As soon as the pleura is opened and pneumothorax occurs, these relations are disturbed. We cause then, whether we use rarefied air or compressed air, in both cases, a markedly altered state, and changed conditions for the maintenance of normal lung volume. With compressed air, as well as with rarefied air, the lung elasticity rests on the air in the bronchi, which is under higher tension than that on the surface of the lung. Whether now the pressure difference is 760 to 768 or 752 to 760 is of no importance."

Many objections brought up by observers to the pressure method are due to faulty apparatus and inaccuracy in technical operation, to be laid aside as unnecessary with a further perfecting of both. On the other hand, much may be said in its favor. One of the main things is the greater ease of applying it, and consequently its more universal employment. Efficiency of apparatus is the key-note, and the subject of lung dilatation and aëration is quite essentially a mechanical one. The phenomena, however, following upon collapse are due, in part, to mechanical means, and in part are probably the results of the complication of the changed mechanical conditions

by the unusual excitation of one or both of the vagus nerves.

The changes incident upon one-sided open pneumothorax, as cited by Sauerbruch, are these:

1. In the respiratory circulation — increased capacity, and speed of blood through the collapsed lung, decreased flow of blood through the other lung.

2. In the respiratory act itself — at first an increased depth and frequency, and later an increased depth and slow rhythm.

3. In the systemic arterial circulation — moderate rise of blood-pressure.

4. In the systemic venous circulation — slight increase in pressure, amounting to about $2\frac{1}{2}$ mm. in the dog.

5. In the systemic temperature — increased loss of heat.

Hnátek says the chief cause of continued and marked rise of blood-pressure in pneumothorax is due to lack of oxygen, which stimulates the vasoconstrictor and vagus centers, while another factor is entrance of air into the pleural cavety, causing, also, stimulation of the centripetal vagus fibers. "When the vagi remain intact in laboratory experiments, the animals succumb more rapidly" (20).

Sauerbruch says that lack of oxygen causes dyspnœa, and also has a tendency to cause a rise in the arterial pressure in the systemic circulation. The dyspnœa, also, may be due partly to the stimulation of the vagus terminals by the collapse of the lung.

Considering again the changes in the respiratory circulation, we find that we have here a lack of oxygen, due to increased flow of blood through the collapsed lung, with but imperfect expansion of the other, giving, in conjunction with the irritation of the vagi terminals by collapse of the lung, dyspnœa. In the arterial circulation we have moderate rise of blood-pressure, due partly to an increased amount of blood returning from the lung to the left auricle, thence to the left ventricle, and so into the systemic arteries; and partly to the increased venous pressure (2.5 mm. in the dog), due to lack of the aspiratory action of negative pressure on the right auricle and venæ cavæ.

Sauerbruch's method overcomes all these, except the increased venous pressure, due to stasis, and even this is corrected by his enveloping rubber bag. For this, however, a large and cumbersome apparatus is used.

The first two — viz., dyspnœa and rise in arterial pressure — can be overcome satisfactorily with a positive pressure within the lungs, and there is left only the element of increased venous pressure, which is but slight.

The question has been raised as to which method of carrying air under pressure into the trachea directly has the greater advantage — tracheotomy or intubation — and in which method are present the fewer unpleasant physiological effects.

G. W. Crile (21), in experiments on dogs, has produced, by rather extreme manipulation, manometric tracings showing that irritation and manipulation of the upper part of the œsophagus opposite the larynx caused a fall in blood-pressure. Further (21), he stated that irritation of the middle and upper part of the larynx caused most pronounced reflex inhibitory phenomena. He also obtained a temporary fall of blood-pressure by pulling up the trachea. The same results have been obtained in this last detail in my experiments, while both pleural cavities were open. Probably this was due to a mechanical effect upon the great pulmonary vessels, diminishing the flow through the lung, and consequently supplying less blood to be pumped from the left heart into the systemic circulation. The purposely severe manipulation of the larynx in intubation in several experiments in this laboratory have, however, failed to produce any marked effect in blood-pressure, as can be seen by reference to the manometer tracings.

The advantages of intubation, as compared with tracheotomy, from the standpoint of infection, however, are distinct. A number of dogs have died from septic infection of the opened pleura, traceable, however, to other causes than insufflation. And although some of the microscopic slides showed exudate, it was but of small amount, and situated rather subpleurally than around the bronchi. In all these cases there was empyema.

In intubation, as in other methods conveying air under pressure to the lungs, care must be taken not to deliver the air under too great pressure. The negative pressure in the pleural cavity, according to Donders, as quoted by von Mikulicz, is — 7 mm. of mercury. This may even be changed to a positive pressure, as in the act of coughing (22), or when vocal sounds are being made (23). In the dog, Büdingen has detected a positive pressure in the pleural cavity of 80 mm. of mercury, due to spasm and closure of the glottis. This would mean about 83 to 87 mm. pressure in the interior of the lung.

Observations made by myself upon three persons in the laboratory show that when one blows steadily into a closed tube connected with a mercury manometer, directly from the lungs, he is uniformly able to hold the mercury well over the 60 mm. mark, without bringing into play the accessory pharyngeal muscles, and without any unpleasant effects. Now, a positive pressure of 10 mm. mercury is sufficient to dilate the lungs against their own elasticity (Matas); therefore each had 50 mm. pressure in excess of what was needed to produce satisfactory expansion of the lungs, had the thorax been open, to approximate the visceral to the parietal pleura. It would seem, then, that any one who can blow steadily for any length of time either upon a musical instrument or in a tube connected with a manometer, or who can sing, can stand the changes in circulation incident to an increased positive pressure, as delivered in the usual way by the insufflation pump when the maximum pressure does not exceed 30 mm. of mercury, and is delivered alternating with, let us say, 10 mm. of mercury on expiration, 18 to 36 times a minute, provided the beginnings of each inflation are gradual.

That the sudden impact of the insufflated air may cause a rupture of the alveoli, and so an interstitial emphysema of the lungs, even when under a comparatively low pressure, is worthy of consideration, as is shown by Sauerbruch, but this danger may be eliminated by inserting a simply constructed safety-valve in the air circuit, and letting the stream of air on gradually, by a diamond-shaped opening in a rotary valve,

as is done in the apparatus in use in this laboratory, designed by J. T. Hoyt. The advantage of having a tube carried directly into the larynx to convey both the respired air and the anæsthetic is plain in cases where there are, aside from the usual apprehensions incident to opening the chest, the danger of closure of the glottis by falling back of the tongue, or of the clogging up of the larger bronchial tubes or the trachea, by mucus or blood in operations on the lung itself. In the two latter cases the advantage in having a negative pressure pump available in the circuit is material. Another advantage of the negative pressure or suction pump is that it more readily carries off the used air from the connecting tube, trachea, and larger bronchi, where the distance between the pump and the canula is considerable. This is necessary in case of a closed circuit of air, but where there is an aperture for the escape of air on the subsidence of the chest, that is to say, in the expiratory pause, near the entrance of the mouth, it is unnecessary. The aspirating pump may be used to draw air out of the pleural cavity after the wound has been closed and the operation completed. Aside from these, there are no advantages in its use.

The objection may be raised that the introduction directly into the larynx and trachea of cold concentrated ether vapor is extremely irritating; and this is probably true. In my experiments there have been no ill effects from it, and it has not been regarded as necessary to warm the ether, but this can readily be done by the method of D. C. Greene, Jr. (24), who places the ether-container in a double cylinder of brass, in the inner compartment of which is warm water and in the outer one hot. The question has been asked, Does not the prolonged intubation injure the larynx? Results in these experiments have not shown it, as some of the dogs were making laryngeal noises soon after the termination of the operation. All six that lived recovered their voices. The intubation period was not as prolonged as is usually the case in diphtheria, and according to Rosenthal of Philadelphia, this is now 120 hours (25). He states that the cause of prolonged intubation is, most frequently, paralysis of the vocal cords; not that prolonged intu-

bation causes paralysis. In the discussion on this subject in the same article, Dr. B. R. Shurly of Detroit states that in 261 intubations performed (in diphtheria) in the last five years (prior to March, 1902), he has had only eight cases where the tube was retained longer than his customary four days; in other words, only eight cases where it was necessary to intubate again, after the tube had once been removed. From this it is clear that the O'Dwyer canula, as used in diphtheria, produces no paralysis, even after four days in the larynx. Of course, the instruments are not quite the same, but the conditions in intubation for artificial respiration appear less unfavorable to good results than in a diphtheritic larynx.

The thorax has been invaded in many conditions, in man as well as in animals; in some cases with success, in others with persistent and discouraging failure. In an article published in 1899, Matas says, "Until the risk of seriously interfering with respiratory function by inducing a collapse of the lung is clearly eliminated or is reduced to a safe minimum, the analogy between the pleura and the peritoneum, from the surgical standpoint of view, will never exist." This is now, perhaps, the most easily overcome of all the differences in the analogy between the two. The analogy ceases to exist after we have said that both are serous cavities into which the viscera, during embryological development, are thrust. In the abdomen we have conditions favorable to adhesion formation; we have a soft and flexible abdominal wall, filled with intestines and omentum, and an absence of negative pressure. It is still filled, after resection of many feet of gut. In the chest we have a rigid wall held expanded by a bony framework. If we remove a portion of any viscus, we have nothing with which to fill the void; we have no omentum to apply to the exposed tissues deprived of their serous covering by operation. In the œsophagus we have but little elasticity, with no mesentery. We have a tendency, moreover, toward constant negative pressure, which makes drainage difficult, and we have a great supply of lymphatics (Sauerbruch) ready to absorb rapidly poisons due to infection.

In many dogs that have died in my experiments, it appears fairly certain that recovery would have taken place instead, had the question of drainage and yet maintenance of negative pressure been elaborated. This has now been more perfectly worked out in operations on human subjects by H. Seidel (26), who places over the operation wound an air-tight case with a window through which inspection may be made, and which is constantly connected with a vacuum filter-pump.

Returning again to the method of increased pulmonary pressure, introduced by means of a canula especially, we find, besides the ordinary intratracheal one in common use in the laboratories, and the old laryngeal canula of Chaussier, modified by Depaul, and later much improved by Ribemont, an ingenious tube by Doyen, and an intratracheal one by Trendelenburg. The tube of Doyen is short and mostly intralaryngeal, and made of aluminum, so that it will not gravitate easily from the larynx when the patient is in the Rose position. The upper end of it is connected with a flexible rubber tube, and so can move up and down with the motions of deglutition. The tube is introduced into the larynx by a specially constructed pair of forceps, which are then removed. The Trendelenburg tracheotomy canula consists of a canula of the usual shape, upon the intratracheal part of which is placed a little india-rubber bag, which can be inflated through a small tube in the side, so as to prevent completely the passage of air around the tube. Quenu says it is not necessary to close the air-passages hermetically in order to prevent the escape of air around the canula. "A feeble pressure of from 3 to 5 mm. (in dogs) suffices to apply the lung against the thoracic breach. After that a current of air suffices; little consequence if it allows some leakage around the canula." The Fell-O'Dwyer apparatus is well known, but in this the advantages of the Ribemont tube are supplemented only by the various sizes of the laryngeal obturators, a lateral opening near the outer end, and the bellows. As far as has come to my observation, the O'Dwyer laryngeal tube, so universally used in diphtheria, has not been applied to intubation for artificial

respiration. In passing, the bivalve speculum of Labordette for the better introducing of an intubation canula deserves mention (27, 28).

Artificial respiration, in one form or another, seems to be the best means to insure the greatest degree of safety to the patient while the chest is open. Efforts have been made for its practical application by many observers since and even before the presentation by Chaussier of his apparatus (29). It is only in the last few years, however, that the attempt has been made to apply it as an aid in operative surgery. H. Milton of Cairo has advocated its application in mediastinal surgery, although he reports a case of removal of the mediastinal glands in an Egyptian fellah without it (30).

Tuffier and Hallion report that one of them has been able to apply with success to the partial resection of the lung in man a proceeding that he has previously experimented upon in animals (31). They do not state definitely, however, what it is. Sauerbruch says, in 1904, that, in spite of the loud praises for it by Tuffier and Hallion, not one case of artificial respiration having been used for operative purposes on the human being has come to his notice.

Sauerbruch, in the same article, reports experiments on a number of dogs and rabbits, most of which he operated upon without anæsthesia.

Hahn reports from von Mikulicz's clinic (32) unsatisfactory results in the surgery of the intrathoracic œsophagus, but favorable ones in unselected gangrene of the lungs.

Von Mikulicz himself says the pneumatic chamber permits intervention without danger of asphyxia upon the heart and the whole mediastinum.

Mayer of Brussels gives a report of Sauerbruch's apparatus, and mentions one dog he, personally, has operated upon (33).

Benjamin Ricketts gives a review of the surgery of the chest, with an extensive bibliography, and publishes his results of operations on fifty dogs, among the successful results of which twenty-four lived over eight days. He makes no mention of artificial respiration (34).

L. Sencert gives a very discouraging list of operations on four dogs, performed during artificial insufflation after tracheotomy on two and intubation on two, in which he lost the whole four by bronchopneumonia. He says that artificial respiration after tracheotomy or intubation permits the animal to support temporarily its lost function, "but in these conditions the dogs die very rapidly of pulmonary complications."

J. B. Murphy of Chicago gives a most comprehensive review of the surgery of the chest, and publishes his results of operations on ten dogs, without artificial respiration (35).

F. W. Parham, in 1898, by means of the Fell-O'Dwyer apparatus, in his second case of traumatic pneumothorax, accompanying resection of a tumor of the thoracic wall, attained a successful outcome. He is so imbued with its value that he believes no operation attempting thoracic resection should be undertaken without having it at hand (36).

Von Mikulicz, in an article appearing in 1904, mentions two dogs that he operated upon, resecting over two inches of œsophagus, one of which was living six weeks after operation, the other dying four weeks after operation, from marasmus and enteritis, due to constriction at site of operation. He thinks the method of operating transpleurally upon the œsophagus will be more serviceable in case of foreign bodies, than for resection (37).

Sauerbruch (38), at the beginning of this year, reports experiences in operating in sixteen cases on the human being with his chamber. The first case was done by von Mikulicz, in which an osteosarcoma was removed with resection of 10 cm. of the fourth and fifth ribs, and broad opening of the pleura. The operation was by a broad flap incision, the flap being sewed back after removel of tumor, and the patient was discharged cured after ten days, the wound healing by first intention.

The second case was that of a woman 53 years old, with carcinoma of the breast attached to the ribs. The first operation had been in 1905, and was a radical one. Sauerbruch operated, resecting 7 cm. of the

third rib. The pleura was accidentally torn. He had to do a plastic operation from the other breast to cover the defect. After operation there was no disturbance from heart or lung. After ten days the transplantation had healed in place. No pneumothorax; no exudate.

Third patient, man 35 years old, bronchial fistula. Opened in third right intercostal space. Intercostal incision 20 cm. long. Adhesions around fistula loosened; open pneumothorax. Margin of fistula at distance of 2 cm. removed with circular excision, and then sutured with catgut. Patient discharged cured after fourteen days.

Sauerbruch says that in cases of gangrene of the lung, his method is of especial value only when there are no extensive adhesions over the affected area, and when the location of the disease cannot clinically be made. He says, "Results of our operations were rather poor." (It will be noted that this report differs from that of Hahn.)

Fourth patient, case of lung-stones. Improvement $1\frac{1}{2}$ years after operation.

Fifth patient, gangrene of lung. Also marked improvement.

Sixth and seventh patients, perforated carcinoma of œsophagus. Bad results. Prognosis poor in the beginning.

Eighth patient, gangrene of whole lobe of lung. Bad result; prognosis poor in the beginning.

Ninth patient, had incision in left ventricle, with simultaneous cutting of left internal mammary artery and vein. Died of loss of blood.

He says that up to the present time the worst results have been those of œsophageal operations, due to difficulty of the whole subject, and to the little practical experience in such work on man. In the first chamber operation on the œsophagus, he says, the patient suddenly died of unknown cause. Two other cases had inoperable carcinoma. Patients died two weeks after operation, of empyæma. He says his fourth œsophageal operation was for carcinoma of the cardia. It showed that such operations on man were possible. The patient did not survive, however. His

fifth operation on the œsophagus was a gastro-œsophagostomy. Male, 51 years old, carcinoma of cardia, 39 cm. from teeth. Operator, Dr. Sauerbruch. Skin incision 40 cm. in the sixth intercostal space. Same length incision in the pleura. Anastomosis was made by button between œsophagus and stomach. During the whole intrapleural operation there was not the slightest disturbance of respiration or pulse. The anæsthesia was very good. The lungs were, during the whole operation, grayish-pink in color, a sign of excellent aëration. The patient died 24 hours later. He was emaciated and run down. This operation, however, proves the possibility of such a surgical procedure.

The remainder of the cases are evidently upon the lung, and are not described.

The experiments in the following two series were performed in the Physiological Laboratory, by the courtesy of Professor John G. Curtis, under the direction of the Department of Surgery, and at the suggestion of Professor Joseph A. Blake, who outlined the form of intralaryngeal canula. Dr. Christian A. Herter gave the use of his Hans Meyer apparatus, for which I am indebted. Dr. Rowland Cox, Jr., furnished a few of the references, and to Drs. Frank C. Wood and Karl M. Vogel I am indebted for the microscopical report on the lungs examined.

In all the experiments, artificial respiration was used after first inducing anæsthesia by ether. The Hans Meyer apparatus was used in the first series and in seven of the second. For the remainder, the artificial respiratory apparatus that is in use in the laboratory, designed by J. T. Hoyt, was used. The air was introduced by intubation, using at first a rigid tube similar to the Fell-O'Dwyer in its extralaryngeal part, but having no opening in the circuit, and fitted with an inflatable india-rubber obturator on the intralaryngeal part. This insured its retention, and prevented leakage of air around it. Later, the short tube, two inches long, connected with a flexible rubber tube, and fitted with the same sort of rubber obturator, was used. Another small inflatable bag, with thicker walls, was placed outside of the mouth to gauge the air-pressure in the intralaryngeal one. (Fig. I.)

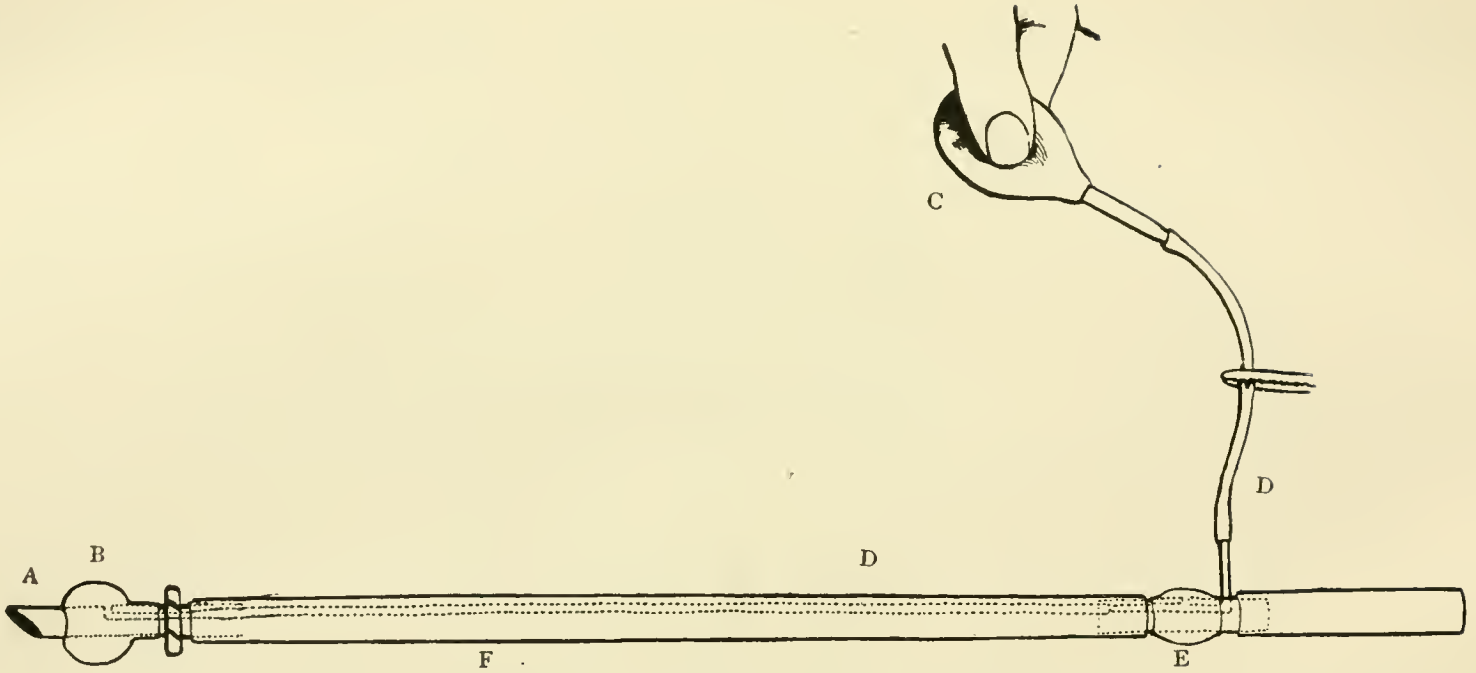

Fig. I.

A. Canula with inflatable bulb, B, inflated with thumb-bulb, C, through small flexible rubber tube, D, and gauged by extra bulb, E.

F is a soft rubber tube, through which respired air passes.

There is a notch on both sides of the head of the canula for the reception of the jaws of the inserting forceps, which are removed after introduction of the canula.

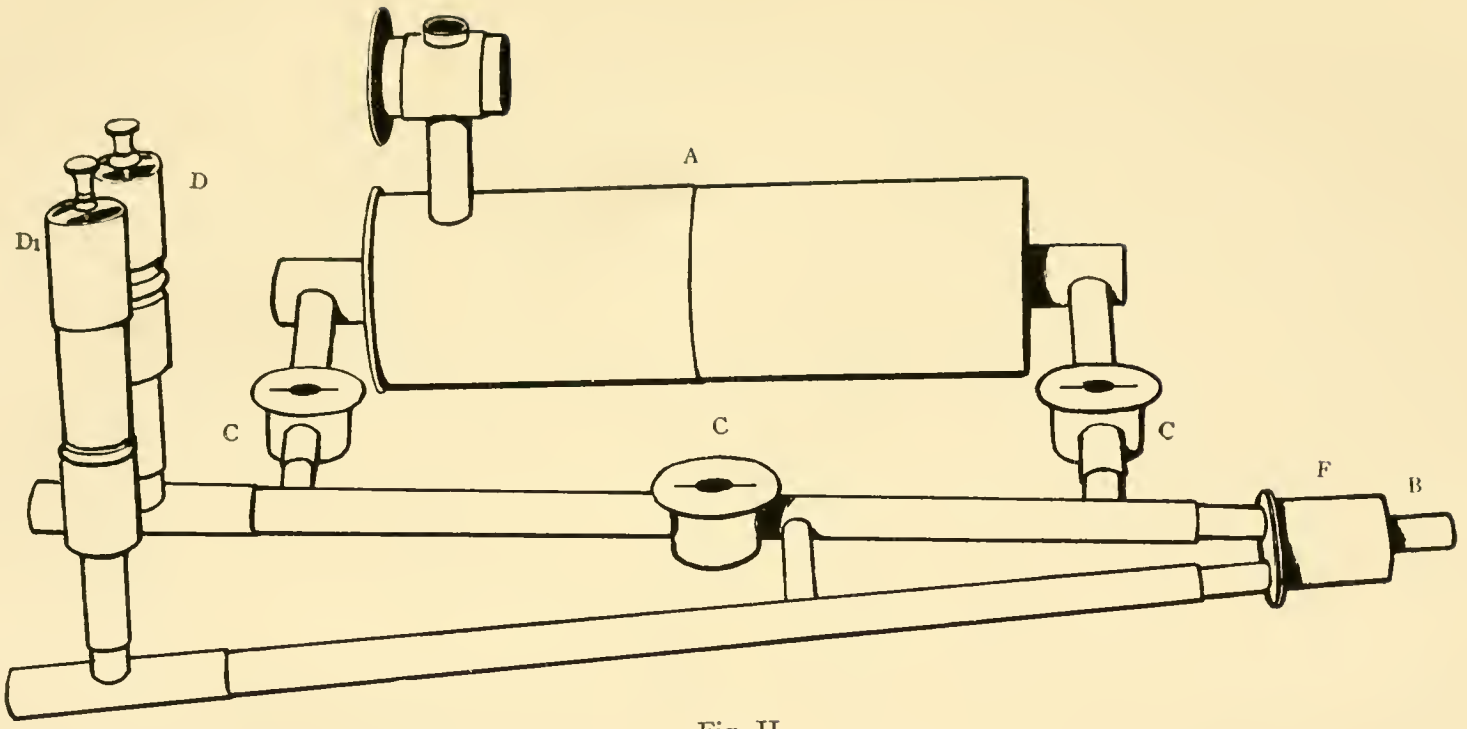

Fig. II.

A. Ether-chamber filled with gauze.
B. Leads to intubation-tube.
C, C, C are valves which are used to direct the positive pressure current of air either through ether-chamber or directly to intubation-canula.
D is positive-pressure safety-valve.
D¹ is negative-pressure safety-valve.
E is an inlet for fresh ether.
F may be used as a receptacle for cotton to filter the air going to the canula.

The ether anæsthesia was administered by a simple device, which allowed of diverting the current of air, either partly or entirely, through the ether-chamber, in this way giving either pure air or part air and part ether vapor, or all ether vapor, at will. (Fig. II.) A positive and negative pressure was used, and a positive and negative safety device was attached during the latter series. The direct observation of the inflation of the lungs was in most instances the guide to the amount of air and pressure used. A manometer was included in the circuit in the last experiment. The animals withstood collapse of the lung very well, provided it was not too long continued.

The details of the experiments follow.

The first series comprises experiments on six dogs, which were killed immediately after the tracings were obtained.

In the experiments of the second series, the dogs, after operation, were set aside for recovery.

First Series

Experiment I. January 24, 1905.

Medium-sized mongrel. Ether.

The administering of ether began at 1:45; carotid entered at 2:30.

When carotid was tied off, respiratory rhythm was much slowed. The carotid was unclamped at 2:50. The blood-pressure at the start was about 90 mm. of mercury. Respiration was shallow, but regular and of average frequency. Ether was administered by mouth, in the usual way and in moderate quantity. Respiration deepened under the additional ether.

Intubation performed — reflexes absent from eye (Fig. III); five minutes later, reflexes returned to a moderate degree in eye.

Intubation again performed — reflexes absent. No change observed in blood-pressure.

3:25. Trachea manipulated, and during manipulation there was marked inhibition of breathing. This occurred while there was no crowding of ether (see tracing for heart-beat). Blood-pressure was scarcely raised, if any. (Fig. V.)

When trachea was severed completely and a tracheotomy-tube inserted, there was only slight reaction.

Trachea was then pulled strongly upward and held there; this produced a shallowing of respiration with a fall of blood-pressure, which continued while it was held up. (Fig. VI.) This obtained when blood-pressure was taken both by carotid and femoral. The femoral artery was used during the latter part of the experiment. The vagus nerve was treated in a similar manner, without any apparent change in the tracing.

As it was suggested that the fall of blood-pressure might be due to increasing of the negative pressure in the pleural cavity, one pleura was opened, and then the trachea was pulled up, with a similar result, accompanying increased amplitude of respiratory effort and heart-beat.

The larynx was then freed and brought out, and while the blood-pressure was still being taken, a finger was introduced into the larynx, with some inhibition of respiratory movements, but no change in blood-pressure. (Fig. IV.) The larynx was then pinched and handled roughly, with no noticeable effect on blood-pressure. The dog was then killed by asphyxia, by clamping the trachea.

Throughout these latter two laryngeal tests and most of the trachea pulls, the eye reflexes were absent.

Experiment II. January 25, 1905.

Medium-sized dog. Irish terrier. Ether.

Femoral artery used for taking blood-pressure.

On intubation twice, a slight fall of blood-pressure occurred, and accompanied with deeper respiration. The fall occurred about eighteen seconds after the tube was successfully inserted. (Fig. VII.)

The thyroid cartilage was then opened roughly through the neck and the intubation-tube inserted, with a slight fall of blood-pressure. When the tube was finally in place, the pressure started up again.

On tracheotomizing, there was no evidence of any fall of blood-pressure. On removing intubation-tube, there was no change in the blood-pressure.

On packing the larynx with gauze, while the eye reflexes were present, there was no change in blood-pressure. (Fig. VIII.) After instituting artificial

respiration and opening chest (Fig. X), pulling up of the trachea gave a fall in the blood-pressure, the same as before chest was opened. (Fig. XI.)

In this test the larynx was irritated without cutting the superior laryngeal nerves. The trachea was surrounded by ligature, using an aneurism needle, which hugged the trachea, and so avoided the recurrent laryngeal nerves. The blood-pressure was then taken after both superior laryngeals were cut, and the result of pulling up the trachea was the same as before.

Note. An interesting fact in this experiment was that the fall of blood-pressure due to pulling up of the trachea was not caused by an increase of the negative pressure in the chest.

Experiment III. February 7, 1905.

Small fox-terrier, female. Ether.

Inflatable intubation-tube used. The tube was inserted without apparent change in blood-pressure. Femoral artery used. Ether was administered through the tube after connecting with artificial respiratory apparatus. With tube removed, the dog was given an excess of ether, and the respiration stopped and blood-pressure fell to 20 mm. Intubation was done and artificial respiration was re-established, with return of heart-beat and pressure to previous condition. Heart-beat had not stopped in this case before the tube was reinserted. This was again attempted, but, failing to accomplish intubation, it was impossible to resuscitate the dog. The heart-beat had stopped here before the tube was inserted.

Throughout this experiment the artificial respiratory apparatus worked well when the chest was open. The blood-pressure was, on an average, 110 mm. of mercury. It was attempted to approximate the rhythm of the artificial respiration to that of the natural respiration of the dog. When it was turned on, and when the bag on the intubation-tube was inflated, there was no noticeable change in the character of the tracing, and the respiration continued even, as before.

This experiment shows the utility of artificial respiration in eliminating poisons, as in an overdose of ether.

EXPERIMENT IV. February 15, 1905.

Small black dog, young, about the size of fox-terrier. Ether.

Tracing taken from femoral artery. Ether was at first given, by mouth, in a tin cone; then an attempt was made at intubation, and no fall in blood-pressure was noticed. It was again attempted successfully, but there was no fall in blood-pressure. This was repeated, but still there was no noticeable fall. (Fig. XII.)

Ether was then pushed, and the dog passed over the danger-point, and cessation of respiration was produced, at first with a slight rise in blood-pressure and then a rapid fall to almost the base line. Heart became irregular. Artificial respiration was then instituted through the tube and kept up at rate shown in tracing (about 58 per minute), which corresponded almost exactly to the automatic respiratory rhythm of dog. The blood-pressure after the curves, simulating Traube-Hering curves, gradually began to rise, and very shortly normal pulse-rate and previous blood-pressure were established. Artificial respiration was then exchanged for automatic respiration on the part of the dog. (Fig. XIV.) This was done three times.

The chest was then opened on both sides and the lungs were allowed to collapse. Artificial respiration was then instituted through the intubation-tube with bag inflated, and the animal kept about the same blood-pressure. The dog was then allowed to die by a cessation of artificial respiration.

Note. A significant point in this case was, that ether may prove fatal, although the efforts at respiration may continue for nearly thirty seconds after the withdrawal of the cone when the ether is being crowded.

After one chest was opened there was slightly less blood-pressure than when thorax was unperforated. After both chests were opened, the blood-pressure was lessened during artificial respiration.

In this little dog the traction on the trachea was not followed by a fall in blood-pressure. To be sure, the pull was not as strong as when the tracheotomy-tube was placed in the trachea and tied in. In this case the trachea was not opened.

EXPERIMENT V. February 21, 1905.

Young fox-terrier. Ether.

A string was passed through the anterior part of the trachea so as not to obstruct breathing. Respiratory apparatus working at 3.25 from center, and at top speed. Intubation again produced no fall in blood-pressure; but when artificial respiration was instituted along with it, the blood-pressure fell from 114 mm. to 96 mm. Pulling up on the string in the trachea caused a fall of blood-pressure, as before. Pulling up on left vagus caused a fall, with a subsequent increase of pressure. Pulling up on right vagus gave a distinct rise of pressure. Pulling up on both vagi caused a rise in blood-pressure. They were both tied off before pulling upon them, but they were not cut with scissors. Intubation canula worked perfectly when it did not leak about the rubber bag.

Intubation produced no fall in blood-pressure. In two instances, when the occluding bag was inflated, so that the lungs were better inflated with air, and the tracing showed increased respiratory depth, then a fall in blood-pressure occurred. (Fig. XIII.) When trachea was pulled up and held, the same fall of blood-pressure was observed as in previous experiments, with a gradual return to initial pressure. It was suggested by a bystander that the fall in pressure was due to pulling up of the vagi, but the vagi were tied off and pulled up in some cases, with a slight fall followed by a rise, and in some cases with a marked rise alone, in blood-pressure. Even after the vagi had been tied off and pulled upon several times, a pulling on the trachea produced the same curve as before. (Fig. XV.) The pleural cavities in this experiment were not opened.

EXPERIMENT VI. February 28, 1905.

Medium-sized dog; part fox-terrier, part bull. Ether.

Femoral artery used for taking blood-pressure. The blood-pressure stood at 142 mm. of mercury.

Intubation performed with digital irritation of larynx and epiglottis, with no fall of blood-pressure. Both vagi tied off sharply, causing rise of blood-pressure after each. When they were pulled up separately or both together, this caused a rise of blood-pressure. When trachea was pulled up both before and after

tying of vagi, a fall of blood-pressure resulted. When artificial respiration at the dog's normal rhythm, but of a volume of $3\frac{2}{5}$ from center, was instituted, the blood-pressure fell from 125 to 116 and remained so. (Fig. XVI.) (This was, I think, due to an overdistention of the lungs.) Both chest cavities were then opened, and the lungs collapsed. Artificial respiration was then carried on quite successfully by means of the inflating intubation-tube and the Hans Meyer apparatus.

Second Series

Experiment I. March 14, 1905.

Fox-terrier. Ether anæsthesia.

Intubation with inflatable canula. Meyer apparatus set at 2 from center. The left chest was opened while breathing normally, and the lung collapsed. The right chest was opened and a triangular piece of lung resected, $1\frac{1}{2}$ inches on a side, in the collapsed condition. Stump of lobe tied off with No. 2 twenty-day chromic catgut. The wounds of chest-wall were then sutured up in layers, and a dressing with shellac applied.

March 15, 1905. Respiration 60. The dog was able to eat.

March 16, 1905. Respiration 40; dog eating.

March 21, 1905. The dog is lively and doing well.

November 1, 1905. The dog died to-day, with tetanoid movements and in a final terminal convulsion, and pregnant at full term. It has been well all summer, with a slight intercurrent mange. It has been tied up and has not had the usual exercise.

Autopsy on dog of Experiment I. November 1, 1905.

Female, well nourished, died this A. M., at 11:00. At 3:00 P. M., rigor mortis well marked. Pregnant at full term. Lungs: Left congested, from the dead animal's lying on that side; right, not congested. Left lung shows no adhesions. Scar of left chest-wall well healed. The operated portion of the right lung proved to be the upper half of middle lobe. It is perfectly healed. Upper lobe is adherent along its anterior border with pericardium. Stump of upper half

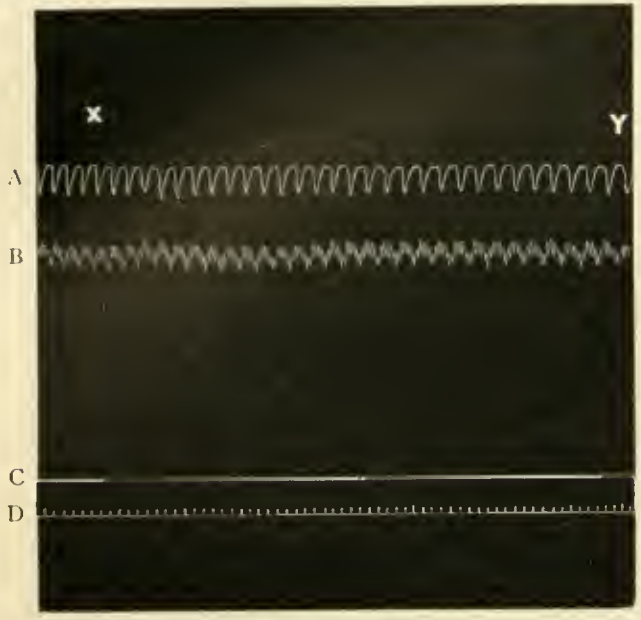

Fig. III.

A. Respiratory curve.
B. Blood-pressure record, taken from carotid.
C. Base line.
D. Time-marking (each division equals one second).
X. Point of beginning of intubation
Y. Tube removed.

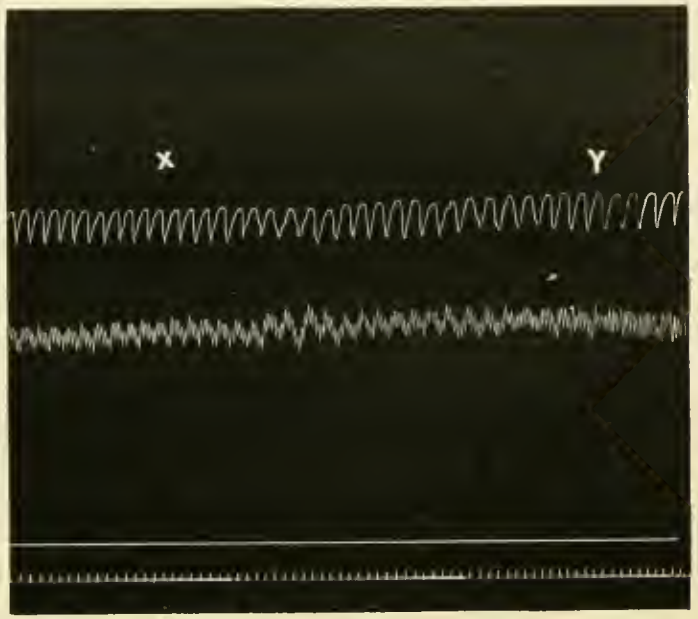

Fig. IV.

X. Commencement of irritation by finger in larynx.
Y. Cessation of irritation.

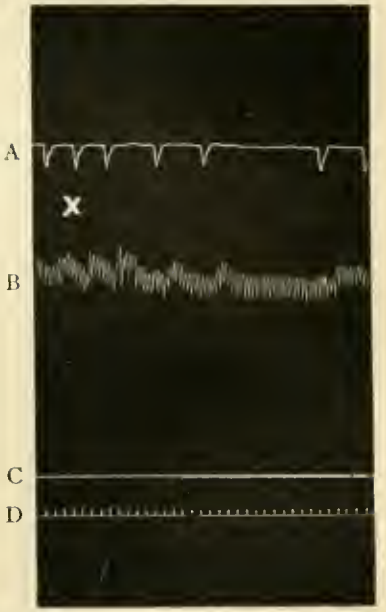

Fig. V.

A. Respiratory curve.
B. Blood-pressure curve.
C. Base line.
D. Time-marking (1=1 second).
X. Point of commencement of manipulation.

Fig. VI.

X. Point of commencement of tracheal pull.

Y. Point of release of trachea.

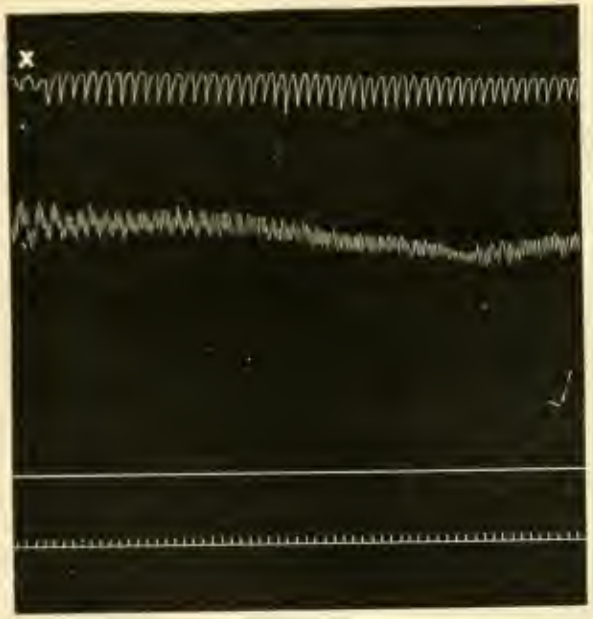

Fig. VII.

X. Point when incubation was performed.

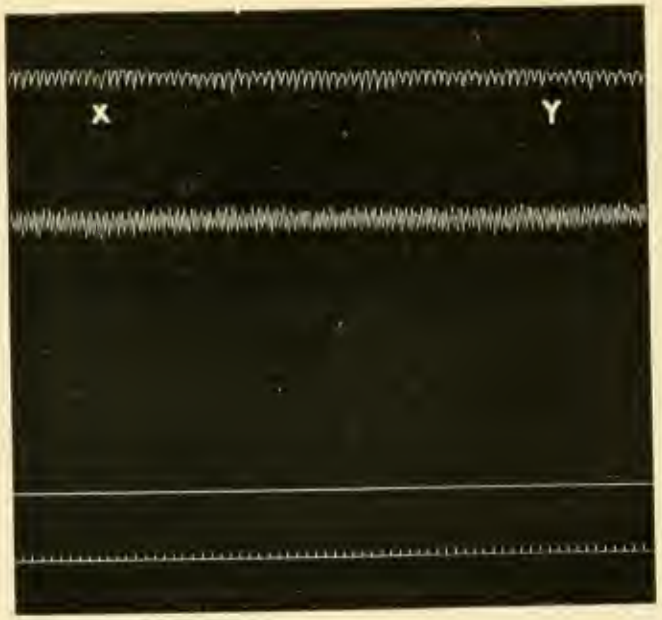

Fig. VIII.

X. Point when packing was commenced.

Y. Point when packing was completed.

Fig. IX.

Shows fall of blood-pressure caused by sharp upward traction on the trachea.

X. Point of commencement of tracheal pull.

Y. Point of release of trachea.

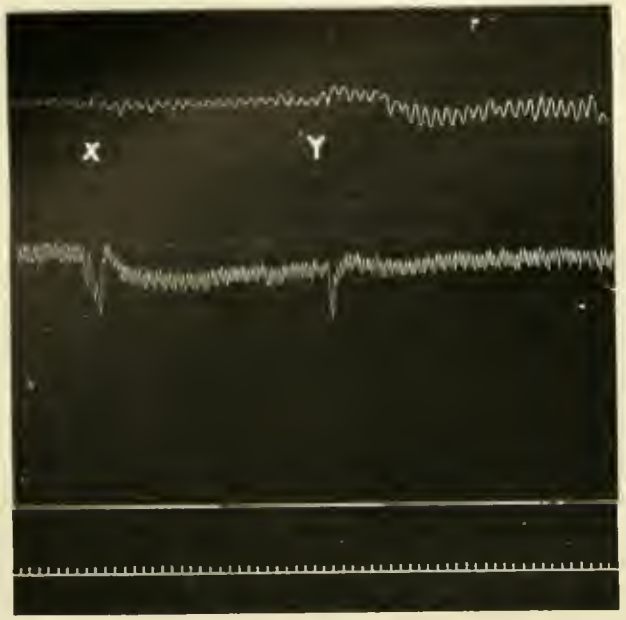

Fig. X.

X. Point of opening, left chest.
Y. Point of opening, right chest.

Fig. XI.

X. Point of commencement of trachea pull after both chests were opened.
Y. Point of cessation of pull.

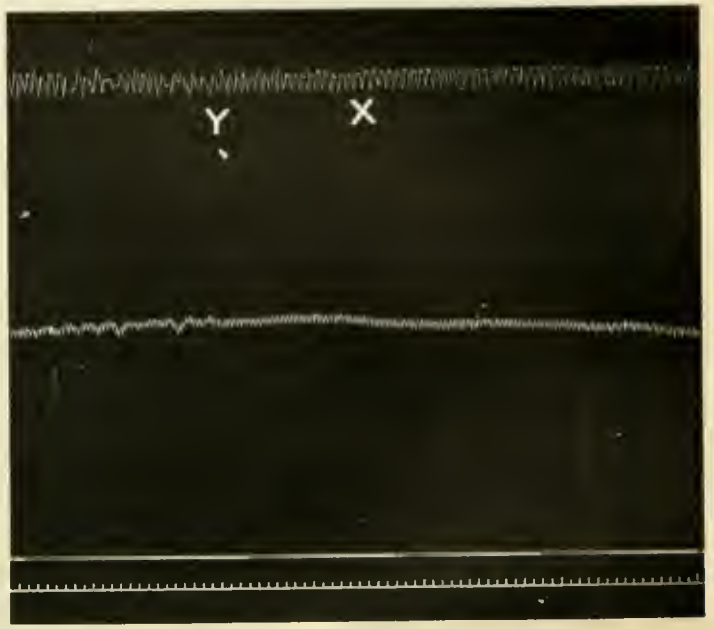

Fig. XII.

X. Point of commencement of intubation.
Y. Point where intubation was accomplished.

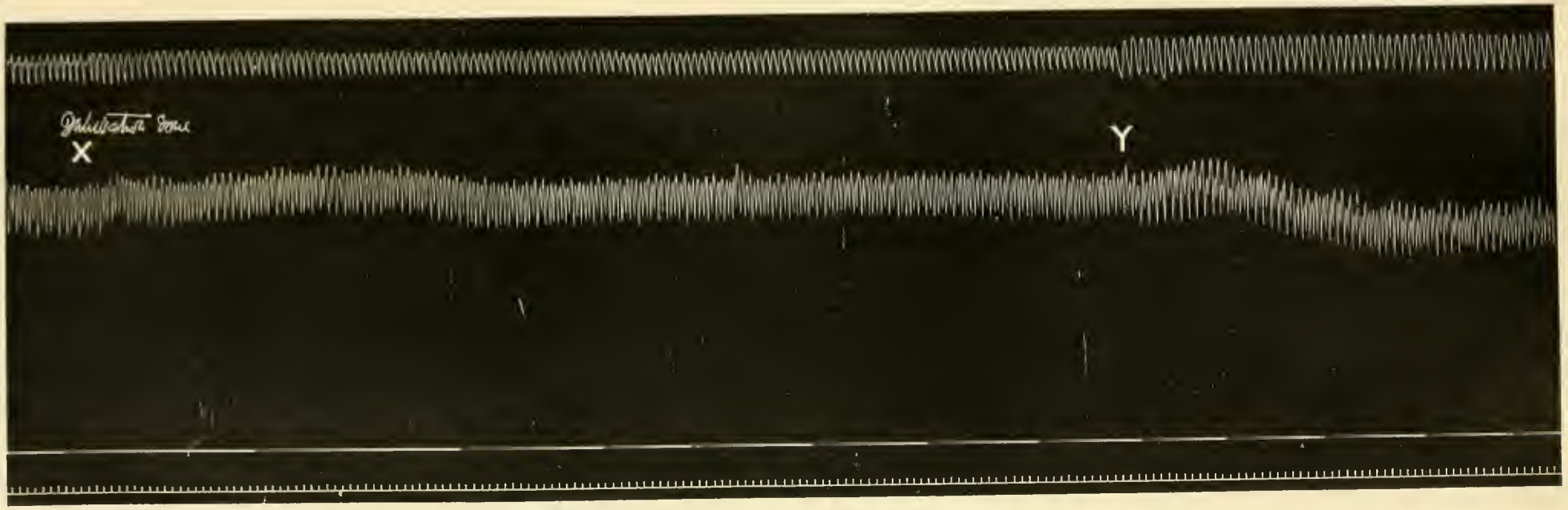

Fig. XIII.

X. Point when intubation was performed.
Y. Point when artificial respiration was instituted.
A. Curve of respiration.
B. Blood-pressure curve.

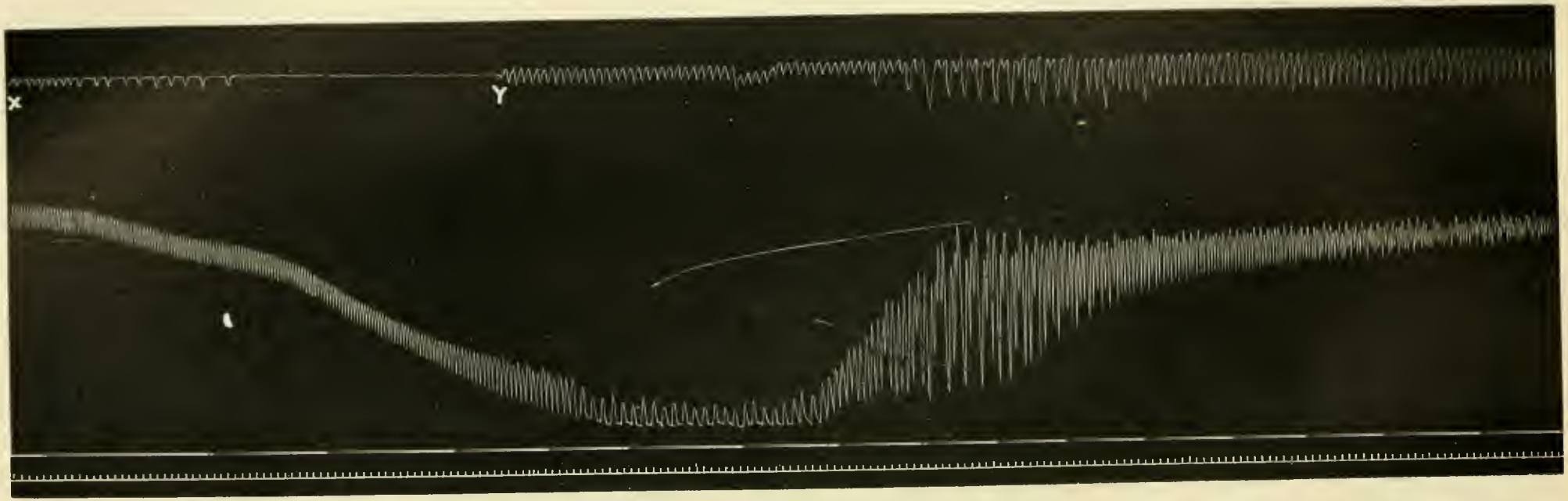

Fig. XIV.

X. Point when anæsthetic was withdrawn.
Y. Point when artificial respiration was commenced.
Z. Point when artificial respiration was stopped and animal resumed automatic respiration.

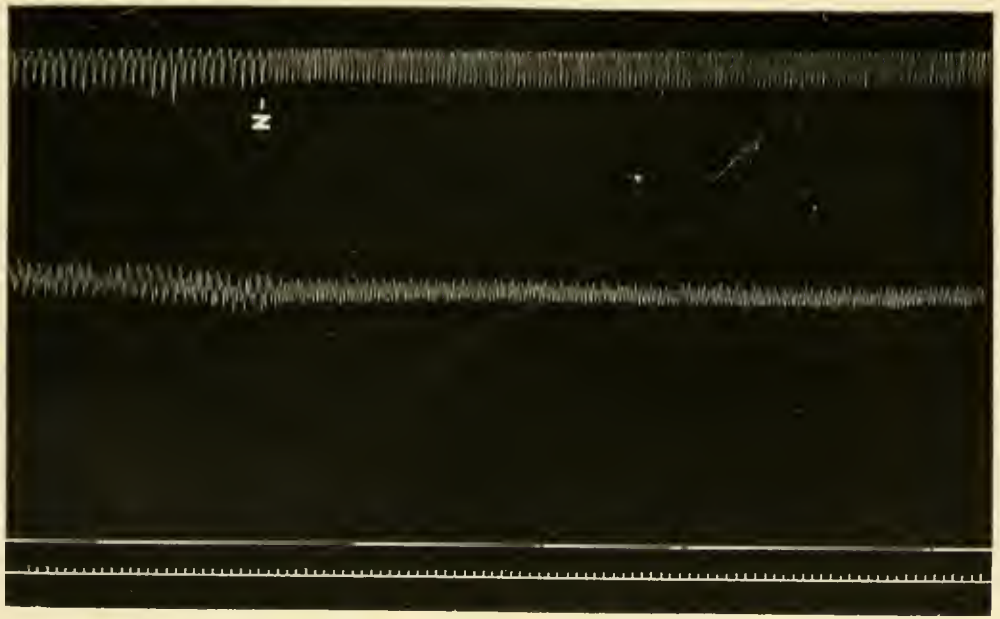

Fig. XIV (continued).

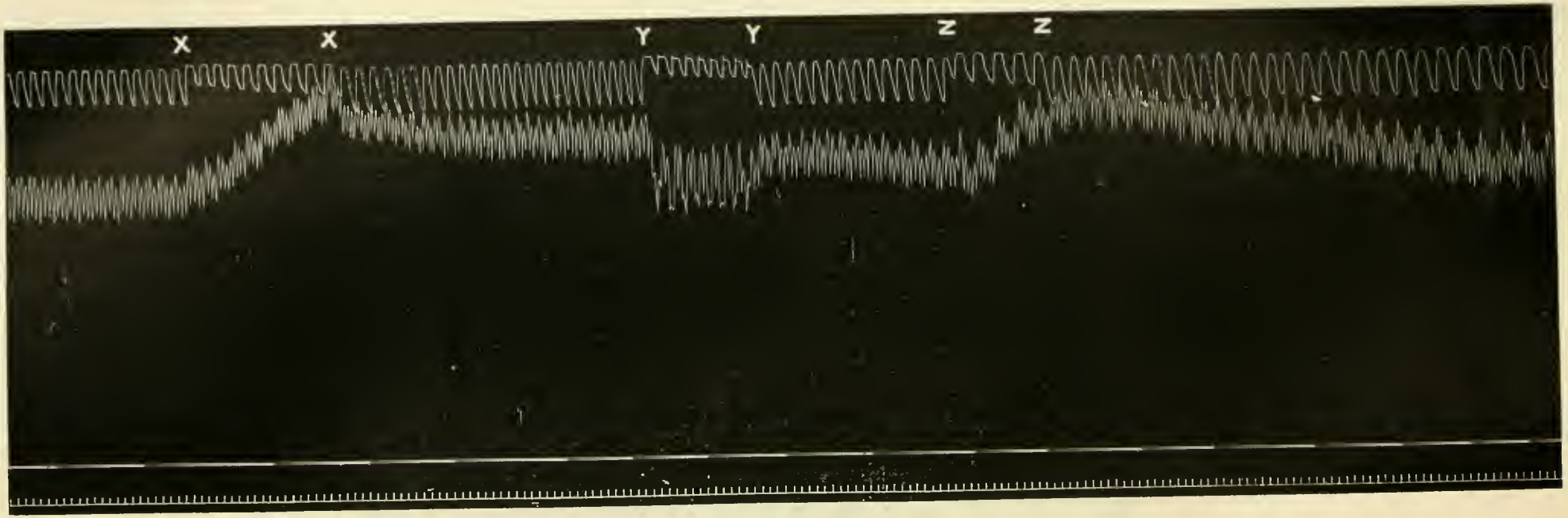

Fig. XV.

X, X. Showing effect and duration of traction upward on both vagi.
Y. Y. Showing effect and duration of traction upward on trachea.
Z, Z. Again showing effect and duration of traction upward on both vagi.

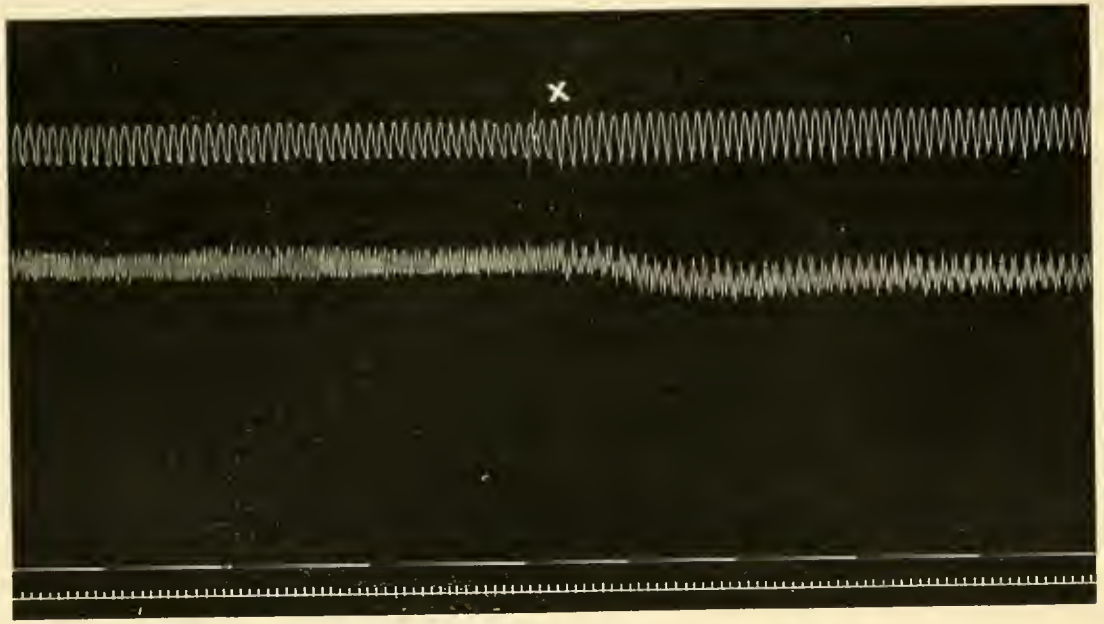

Fig. XVI.

Shows fall of blood-pressure incident to instituting artificial respiration after intubation.
X. Point when artificial respiration was established.

of middle lobe is also adherent. Lower half of middle lobe, the same. There is an adhesion between the operated stump and the upper lobe. Dense adhesions between operated stump and lower half of middle lobe. Small adhesion between lower lobe and pericardium. No gross consolidation in either lung. Microscopical examination not made.

Heart, contracted in systole.

Stomach, normal.

Intestines, anæmic, normal.

Liver, shows fine mottling, moderate degree of congestion, is not friable, but somewhat waxy in feel.

Pancreas, large, pink, normal. No hemorrhages.

Kidneys: Right, markings distinct, capsule very slightly adherent, cortex somewhat mottled; left, capsule not adherent, otherwise the same as right.

Bladder, empty, firmly contracted.

Suprarenals: Right, soft interior; left, normal.

Spleen, small and pale.

Uterus, contains five pups at term. Around each placenta is an accumulation of dark greenish material, which is outside the amnion and is not meconium.

Thyroid, somewhat dark.

Brain, normal.

EXPERIMENT II. March 22, 1905.

Small yellow dog, female, in good condition. Ether.

Respiration before opening chest, 48 per minute. Hans Meyer apparatus and short inflatable intubation-tube was used. Artificial respiratory machine working at 52 per minute, at 2 from center, delivering 224 c.c. of air at each stroke. This was not delivering sufficient air, and later was increased to top speed, and 3 from center. Both chests opened at 4:15. Tube and respiratory apparatus worked well. Tube was removed at 5:15. A large piece of lower lobe of right lung removed, while both chest cavities were kept open. The entire chest was open for 25 minutes, during which time ether was given through the apparatus, and the heart-beat remained strong. The lower lobe of right lung was grasped by the thumb and finger and a large part of it delivered and transfixed several times, then ligated circularly with No. 2 catgut and cut off. The remainder of the lung was dropped back

into place. There was sharp bleeding on transfixing, which stopped on ligation of the lung. On closing the chest-wall by layer suture, it was attempted to empty the chest cavity of air by its own movements. A shellac dressing was applied.

Autopsy on Dog of Experiment II.

The dog died March 24, 1905.

On the first day after operation the respiration was 60, and labored.

On the second day after operation the respiration was still 60, but more labored. The dog cried out at intervals of ten minutes, and later oftener. Five centigrams of morphine was then given hypodermatically, and in seven minutes the animal stretched out with increasing dyspnœa, and died. The autopsy was performed immediately. Right wound clean, except for a drop of pus in one of the skin stitches. Right pleural cavity filled with fibrine and bloody serum. The wound was perfectly tight. The right lung presented four lobes, the lowest small. The half of the one next above had been removed. Sutures firm and holding well. The root of that lobe was swollen and hard. All the other lobes were atelectatic, with patches of aërated lung tissue. The left chest wound was clean and tight. The lung was collapsed on opening chest, and no air sucked in. Pleural cavity contained bloody serum. When the lungs were removed, the left one inflated easily and completely; the right one but a little, and in patches. The pericardium contained bloody serum of lighter color. Heart: Right ventricle flabby; left, normal. Other viscera normal.

Microscopical report showed congestion and subpleural exudate in lung.

Experiment III. April 19, 1905.

Small dog, fox-terrier, old. Ether.

The Hans Meyer apparatus with anæsthetizing attachment was set at $3\frac{3}{5}$ from center. Intubation with short inflatable canula. Speed 52 per minute. Incision was made into left chest, the lung collapsed, and the chest aperture was kept open with artery-forceps. The right chest was then opened and the lung collapsed. Breathing all the time was carried on artificially. The lungs were not inflating suffi-

ciently, so the stroke of the Meyer apparatus was set at $5\frac{3}{5}$. Ether was administered by the attachment quite satisfactorily. After right chest was open, a piece of the middle lobe was removed, using a chain suture of No. 4 catgut to stop the hemorrhage. The chest cavities were then closed, and a canula inserted, attached to the negative pressure side of the Meyer apparatus, and the air aspirated from the pleural cavity. Artificial respiration was then stopped and the dog bandaged up. The chest cavities were open about half an hour, the left somewhat longer than the other. One hour after completion of operation, the dog was on his feet walking about, and apparently quite comfortable.

Autopsy on Dog of Experiment III. April 24, 1905.

The dog died three days after operation and was kept on ice.

Some suppuration in the left chest-wall wound was found. A very little fibrinous pleurisy was present in left chest cavity. Left lung normal. Right lung compressed. Stump of sectioned lobe firm and gray. Pleural cavity filled with fibrin, and turbid; slightly bloody serum. There was no organized clot; therefore probably but little direct bleeding. Pericardium contained a little red serum, but not so much as in experiment II.

No microscopical examination was made.

EXPERIMENT IV. May 16, 1905.

Part fox-terrier and bull. Ether.

Meyer machine set at 4 from center. It was found not to be inflating the lungs sufficiently when the left chest was opened, so the crank was moved up to 6 from center. The safety-valves worked well and easily. Ether given through special attachment, which worked well. The rhythm was about that of a normal dog of this size. The right chest was opened and the lung found to be inflating and collapsing well. (While this went on, chest-wall remained quiet.) A piece of the middle lobe of right lung was removed, the stump sutured with through-and-through sutures, and then tied circularly. When the well-aërated lung was handled, the pressure of the fingers caused areas of partial atelectasis, which later became again inflated.

The chest was closed on both sides, and the last opening in each wound was closed, while the lung was in full inflation so as to leave the minimum of air in the pleural cavity. The wounds of the chest-wall and of the lung were sutured with No. 2 catgut. The external wounds were sealed with a 25-per-cent formalin solution. The operation took about 1¼ hours. Both chests were open about one hour. The work was done slowly and more carefully than in the preceding, and less of the lung tissue was removed.

May 18th, noon. Dog rather stupid, and lying down; does not seem straining for breath as much as the two previous ones.

October 23d. The dog is alive and well.

Autopsy on Dog of Experiment IV. October 23, 1905.

Dog operated on May 16th. The dog has been well all summer, except for intercurrent mange. Killed by chloroform. Well nourished. Musculature good. Thick subcutaneous fat. The right lung appears normal in color. The upper half of the middle lobe was the one operated on. Line of operation is healed, with a slightly bluish cicatrix. There are but few adhesions. One delicate one, between the upper division of middle lobe and upper lobe. One broad, dense one extends between the upper portion of middle lobe and lower portion of middle lobe; one string-like one between the upper portion of middle lobe and the mediastinum; one large band-like one between lower portion of middle lobe and upper surface of diaphragm and mediastinum. One band between lower lobe and costal pleura posteriorly. Healing has apparently been perfect; lung tissue normal. Adhesions from lower edge of lung incision to upper surface of lower division of middle lobe. Left chest, scar of chest-wall incision hard to find. Adhesion between middle lobe and mediastinum, delicate. No other adhesions.

Heart and other viscera normal.

After lungs were removed, both the operated portion and the rest of the lungs dilated perfectly with the bellows.

Microscopical examination showed no pneumonia.

EXPERIMENT V. May 17, 1905.

Small, short-haired, yellow dog. Ether.

Hans Meyer machine set at 6, delivering 40 respirations per minute. Inflation was found to be slightly excessive, so some air was allowed to escape through the safety-valve. Left chest punctured with trocar and canula, which was left in, so leaving an open pneumothorax, as in some of Aron's experiments (39). Right chest opened at 3:38 P. M. Piece of lung resected, triangular in shape, and sutured with No. 2 catgut, so as to approximate the pleural surfaces. It was then dropped back into the pleural cavity at 4:10. No bleeding. The wound was then closed up at 4:15, and the skin at 4:20. Through this experiment the artificial respiration was carried on through the inflating intubation-tube, and ether was administered through the special attachment. Both worked perfectly. The main point in this experiment was that there was a careful suture of the pleura, preventing any leakage of blood, and giving the minimum oozing of serum. After handling, the lobe immediately became congested and did not dilate as well as previously under artificial respiration.

May 18, 1905. Dog bright and lively, wagging his tail and eating.

May 23, 1905. Dog in good condition.

October 25, 1905. The dog is still alive.

Autopsy on Dog of Experiment V. October 25, 1905.

The dog has been well all summer. Quite lively, and breathes normally. It was killed with chloroform. Respiration ceased before the heart-beat.

Well nourished. Scar healed perfectly all the way through.

Right lung showed slight congestion from chloroform. Left one, the same. No abnormal amount of fluid was found in either pleural cavity. The lobe operated upon was the upper division of middle lobe of right lung. From this there is an adhesion extending to the costal pleura at the site of the incision from one end of the lung incision. The lung was healed, with slightly bluish pigmentation along the line of cicatrix. There was an adhesion from the other end of this

cicatrix to the mediastinal pleura, and also to the costal pleura. There were also dense adhesions between the lower surface of upper portion of middle lobe and upper surface of lower portion of middle lobe. There are also some firm and some elastic thin adhesions between the lower portion of middle lobe and upper surface of diaphragm. There were no adhesions in left pleura. The left lung was quite normal.

Heart and other viscera normal.

Upon removal from the chest, both lungs inflated perfectly with bellows.

Experiment VI. May 23, 1905.

Small mongrel, black-and-tan, female. Ether.

The Hans Meyer apparatus was set at 6 from center, delivering 36 artificial respirations per minute. Inflating intubation-tube used. The left chest was punctured and the canula left in. The right chest was opened and a portion of one lobe seized in the fingers and drawn out, and resected distally to a clamp. One bleeding-point was caught and ligated. The lung wound was then sutured over and over, with an effort to approximate the pleural surfaces, leaving a longitudinal sutured wound. After suturing there was no bleeding from the stump, which was dropped back into the pleural cavity. The parietal pleura and the chest-wall were then sutured. No. 2 catgut was used throughout. Ether was administered through the special attachment. An attempt was made to close the chest wound completely while the lung was inflated. The canula was drawn out of the left chest when lung was in similar condition. During the course of the operation the artificial respiratory apparatus was disconnected while both chests were open. The dog showed signs of commencing asphyxia, which were at once relieved, on reconnecting and recommencing the artificial respiration.

October 11, 1905. The dog is still alive.

Autopsy on Dog of Experiment VI. October 11, 1905.

The dog has been well all summer.

Dog was killed with chloroform. The left lung was normal, with only the degree of congestion due to chloroform. There were no adhesions and

no fluid in left pleural cavity. The right lung was congested to the same degree as left. Upper lobe shows no adhesions. Middle lobe adherent to lower portion of lower lobe, over stump of upper portion of lower lobe, which had been operated upon. There were adhesions from the stump of the operated portion to several adjacent parts. There were, however, no adhesions to costal pleura at site of scar, and no adhesions from cicatrix of lung, except at either end. The cicatrix was firm, smooth, and slightly darker than the rest of lung. Stump crepitates, as do the rest of the other lobes. After lungs had been removed from chest cavity, they inflated throughout with bellows.

Heart, normal.

Liver, congested and friable.

Pancreas, congested.

Intestines, normal.

Microscopical examination of lung showed no inflammation and no emphysema.

EXPERIMENT VII. October 31, 1905.

Fox-terrier. Ether.

The Hans Meyer apparatus, with special etherizing attachment, was used, set at $5\frac{1}{2}$ from center, delivering 616 c.c. at each stroke. Safety-valve set at moderate pressure. Inflatable intubation-tube was also used. Ether commenced at 10:55 A. M. Intubation was performed at 11:05, but was not working well, on account of a leak. Intubation canula repaired, and intubation done again successfully at 11:20. From 11:05 to 11:20 the dog breathed by its own effort, although the left chest had been entered with the trocar and the canula left in. The operation commenced at 11:30. The chest was opened on the right side by a simple incision, following the curve of the ribs. Two ribs were then laid bare, and after ligating around them in two places, they were cut between the ligatures, and broken and turned back in the axillary line. This gave a good exposure of the lung, which was being inflated well. An accessible lobe was then seized and drawn out and caught across its pedicle with a clamp. It was then amputated, and a chain ligature applied to prevent hemorrhage; this was of silk. Then an attempt was made to approximate

the serous surfaces and to cover over the stump with visceral pleura by a Lembert suture. There was no leakage from the stump, and no blood from the lungs by mouth. The stump was then dropped in and the wound closed by layers, suturing first the rib-flap in place. There was some oozing from the parietal pleura, and there was much sponging of blood and fluid from the pleural cavity. Some bichloride from a compress ran in while the intubation canula was being repaired.

During about 15 minutes from 11:30 on, there was a time when the intubation canula did not work, and the dog kept up respiration, and so remained alive, although respiration was very labored, and the dog very blue. This indicated that the collapse of the left lung was not complete. It was attempted again by another trocar puncture. At 3:30 the same day, the dog had recovered from his anæsthesia, was restless, and crying a little. His breathing was 24 per minute, and labored. At 3:45 the dog was quiet, and apparently half asleep. Respiration was 40 at 4:00 P. M., and 50 at 9:30 P. M. At 10:00 P. M., November 1st, 33 c.c. of bloody serum was aspirated from right chest. Left chest was aspirated at the same time, but no fluid was obtained. Respiration remained at 50 per minute. November 2d, 8:30 P. M., respiration 46 per minute. November 3d, dog still alive. In the evening, 9 c.c. of alcohol were injected hypodermatically, and 30 c.c. of red turbid fluid aspirated from right chest. November 4th, 8 c.c. of alcohol injected by hypodermic syringe. November 5th, dog had a cold, moist nose, still had labored breathing, but was apparently better than yesterday. November 6th, dog died at 3 A. M.

Autopsy on Dog of Experiment VII. November 8, 1905:

Dog died November 6th, and was put in cold storage.

Pus was encountered between the intercostal and pectoral muscles. It extended up between the layers of muscular facia well toward the axilla on the right side. It communicated with right pleural cavity through an aperture half an inch in diameter at the

sternal extremity of the cut ribs. The sutures, which were of silk, were bathed in pus. The right chest was distended with thin pus and fibrin, and the right lung was quite flattened out. The diaphragm was crowded downward. There was a seropurulent pericarditis, with great distention of the pericardium. The heart was contracted in systole. The left chest contained but little fluid. The left lung was congested, but otherwise normal, save for adhesions between the mediastinal surface and the pericardial pleura. (This was apparently an extension from the pericarditis.) The stump of the operated lobe was free in the empyema fluid. The pleural stitches had given way and the first ligating chain-stitch was quite easily pulled off. None of the vessels had been bleeding. When the chain ligature was removed, the thrombi from one or two vessels squeezed out easily. The thrombus in one of the main arteries to the lobe was hard and quite adherent to the coat. It extended into the artery about three sixteenths of an inch. The abdominal viscera were apparently normal.

Microscopical Report. Lung tissue collapsed. Peripheral or subpleural exudate slight in amount.

Experiment VIII. November 9, 1905.

Medium-sized black-and-white dog, male. Ether.

The experiment was brought to a sudden termination, due to failure of the apparatus (canula) to exhaust properly while in the larynx. The inspiration was working well, and the expiration also, for about forty minutes, but suddenly the expiration ceased and the lungs inflated as much as the pressure reduced by the positive safety-valve would let them. The intubation canula was then withdrawn and reinserted, with no better result. The chest on both sides had been opened; the left one with canula and the right one with a wide incision extending well between the ribs to near their angle. The operation of removing about one half of the middle lobe of the right lung was partially completed when the accident occurred. The Hans Meyer apparatus was working perfectly, and the trouble seemed to be beyond the canula. The autopsy showed but little blood in the bronchia of the operated lobe, and none in the bronchia of the right chest. In

this case, after the canula had been inserted in the trachia and held there, on account of its failure to work in the larynx, there were a few voluntary efforts at breathing on the part of the dog, but the heart had ceased to beat. Evidently, death occurred from failure of the heart, from some mechanical cause.

In all the foregoing experiments the Hans Meyer apparatus was used.

EXPERIMENT IX. November 15, 1905.

Fox-terrier, male. Ether.

Hoyt's artificial respiratory apparatus used, with inflatable intubation canula and special anæsthetizing apparatus. Operation was begun at 11:55 A. M. with intubation-tube in place. The animal was placed on its stomach, and chest was opened posteriorly on the right side. Two ribs were resected for $2\frac{1}{2}$ inches, having first stripped off the periosteum. The chest cavity was entered at 12:10. The degree of inflation of the lungs was noted, and the aspiration of the air was found to be too little, so more vacuum on the exhaust circuit was produced. The amount of inflation and suction was then balanced, and required no changing throughout the operation, which ended at 2:15 P. M. The presenting lobe of the right lung was delivered, and the visceral pleura commencing a half-inch from the root of the lung was stripped off toward the root. The main bronchus was then tied with silk and separately the vessels. An effort was made to cover the ligated stumps, which were ligated, after transfixing the tissues, with the visceral pleura, which had been stripped back. The attempt, however, was not successful, as the stitches tore out easily. The left chest cavity was perforated with a large canula at 12:35. After several minutes some blood was blown out through the canula. This continued in small quantities for from a quarter to half an hour. The stump of the right operated lobe was then dropped back, and the chest wound sewed up with silk and silk-worm gut, layer by layer. It was impossible to approximate the rift in the parietal pleura. The muscles and fat layers, however, occluded the inlet. There was no attempt to aspirate the air from the right chest cavity, as it was thought that the partial collapse of

the lung would be more favorable to repair. Air was then aspirated from the left chest, and the dog placed in its cage at 2:20. At 3:15 the dog was recovering from its anæsthesia, shivering, and making laryngeal noises.

November 16th, 9 P. M. Dog appears fairly comfortable, quiet, and licking himself.

November 17th, 11:15 A. M. Dog quiet, and breath-

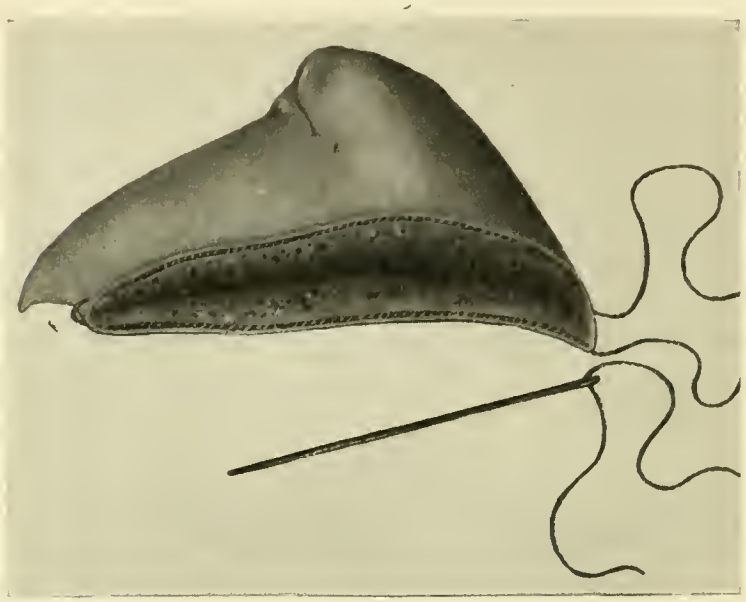

Fig. XVII. Shows the method of passing the first ligating suture subpleurally around the portion of lung to be removed. This is a schematic drawing, and the distal part of the lung has been represented as cut away, in order to show the position of the suture. In the operation this portion is really not cut away till after the ligating suture is tied, as shown in Fig. XVIII, causing a compression of all the vessels and bronchial tubes, but not cutting off the capillary circulation of the visceral pleura beyond it.

ing 20 per minute. Has slight subcutaneous emphysema in neck and on right side.

November 18th. Dog quiet, and breathing 17 per minute, and quietly. Subcutaneous emphysema still present, but in a less degree. Dog is apparently quite comfortable, and takes notice of the approach of any one.

November 20th, 10:00 A. M. Dog quiet, breathing 26 per minute. Rather apathetic; temperature 105°.

Second Operation. The chest cavity was opened at 11:00 A. M., under ether, through the original incision,

which appeared clean, except for slight reddish turbid serum. On opening the chest cavity no fluid escaped until dog was turned on his side. Then 60 c.c. of reddish turbid serum escaped. The dog recovered from ether with increased frequency of respiration (56 per minute). A drainage-tube was employed and a sterile dressing applied. 9:30 P. M., dog breathing more slowly.

November 21st. Tube removed; animal looking better; respirations 24 per minute.

November 27th. Dog still alive and fairly well. Is coughing a little, but not severely.

November 30th. Dog apparently better.

December 6th. Dog eating and walking around, but coughs severely. Jumped off a table three feet high.

December 18th. Dog quite comfortable, but coughs still.

December 26th. Dog still alive, but is very thin, probably due to some chronic sepsis.

March 21st. Dog is alive, frisky, and well, and has put on weight. Has a general subcutaneous emphysema, extending back to haunches and forward to neck, and ventrally within 1½ inches of median line.

March 31st. The dog is still alive.

EXPERIMENT X. December 7, 1905.

Bulldog, female. Ether.

Hoyt's apparatus, with inflatable intubation attachment. Operation commenced at 10:55, when intubation was performed, and ended at 1:30. There was considerable mucous discharge from the trachea, which necessitated removing the tube twice and replacing it, before the operation was under way. The left chest was punctured with a canula, and the air admitted. The right chest was opened by an incision in the back, resecting portions of two ribs. The whole right lung was delivered and inspected, first by lobes, and later as a whole. A rent, caused apparently by traction on the lung, was sewn up and the lung dropped back. Several lymph-nodes at the root of the right lung were removed. The wound in the right chest was then sewn up and the air aspirated from the left chest, closing the left wound. The dog was then

placed in the dog-box. Dog died about 2:30 P. M. the same day. At autopsy, some blood (about an ounce) was found in the left pleural cavity, and a puncture was found in the left lung. On the right side there was no special amount of blood found, but on opening the chest both lungs were found collapsed and dark

Fig. XVIII. Represents the subpleural suture as drawn tight and tied. The portion X is then cut away, leaving a V-shaped wound of the lung, which is then sutured as in Fig. XIX, bringing the edges of the wound together and coapting the pleural edges as in Fig. XX (but not opposing the serous surfaces as in the Lembert suture of the peritoneum). This covers in the ligating suture and shuts off the cut edges of the bronchial tube from the free pleural cavity.

red. The dog had apparently died from leakage of air into the pleural cavities, either through the lung or through the wounds in the chest-wall. Probably the former.

EXPERIMENT XI. December 8, 1905.

Small mongrel — bull and fox-terrier — male. Ether.

Hoyt's apparatus used, with inflatable intubation attachment. Intubation was performed at 11:00 A. M.,

and repeated twice, on account of some stoppage in the canula. The operation was begun at 11:30 A. M. and ended at 1:30 P. M. Right chest opened with blunt instrument, and kept open with a canula. Left chest opened in front, at about the level of the fifth rib. No ribs resected. The upper lobe was removed first, and before ligatures were applied the stump slipped from the grasp, causing profuse hemorrhage, which,

Fig. XIX. This represents the ligating suture as tied and the distal portion of the lung cut away; with the second or coapting suture in place, ready to draw up and tie.

however, was controlled by grasping it between two fingers. A silk ligature was then applied by transfixing the pedicle and ligating around the stump. The lower two lobes were then ligated in a similar way, and the rest of the lung removed, making virtually a total extirpation of the left lung. The ligatures of the pedicles, which were left long, were then passed through one of the skeletal muscles, drawing them tight and suturing the stump into the posterior angle of the chest

wound. The chest wound was then closed layer by layer, the air aspirated from the right chest cavity, the right wound closed, and the dog placed in the dog-box. At 4:15 P. M. the dog was alive and sitting up, and breathing about 24 respirations per minute.

Dog died at 8:45 A. M., December 14, 1905, six days after operation.

In this experiment and the preceding one, negative as well as positive pressure was used during the operation, which was efficient, and as near perfect as could be desired throughout the entire time of operation.

Autopsy on Dog of Experiment XI. December 14, 1905.

There was a leak in the wound of the left chest, at the outer angle, apparently caused by a slight infection, and of recent development, allowing an ingress and egress of air through the stitch-holes made by the silk suture. The left chest cavity contained considerable fibrin and a little reddish pus, but it is evident that there was no extensive empyæma, as in experiment X. The silk ligature around the vessels and bronchi was holding well. Infection was at the site where stump was sutured to skeletal muscle. There was about 4 c.c. of bloody pus in right chest cavity. Right lung was congested and collapsed, but not atelectatic. There was no negative pressure detected in right pleural cavity upon opening it. There was no pericarditis. The heart contained some dense and whitish clots, whether of ante-mortem or post-mortem origin can only be told by a microscope. The autopsy was performed on the heart, not over two hours after the death of the dog. There was but little healing in the wound of the chest-wall. The left lung was found completely ablated, with the exception of a small piece of lung tissue upon the pedicle, about the size of the little finger nail. Cause of death was apparently entrance of air into the left chest cavity, allowing the mediastinum to collapse upon the right lung.

Microscopical report showed but little exudate in the lung tissue.

EXPERIMENT XII. December 19, 1905.

Bull-terrier, young. Ether.

In this operation the right chest was not perforated. The Hoyt apparatus was used, with inflatable intubating attachment. The left chest was opened at about the fifth interspace, and the ribs held wide apart by a retractor. The entire lung was then grasped and drawn out, the pedicle pierced with a blunt needle, and a chain ligature of braided silk applied. The lung was then amputated and the stump cauterized by heat. The chest wound was then closed by placing around the two separated ribs a strong ligature, drawing them together, then uniting the muscular and fascial walls layer by layer, in different planes, finally suturing the skin with interrupted sutures of silk. The wound was then brushed with a forty-per-cent solu-

Fig. XX. This represents the completed operation on the lung.

tion of formaldehyde. There was but little bleeding. Operation began at 11:15 and ended at 1 o'clock, the respiratory apparatus working perfectly throughout.

December 22d, 3:30 P. M. Dog appears comfortable, and wags his tail when spoken to, but is breathing more rapidly than normal. He has also been eating some.

December 24th. Dog died quite suddenly, at 11:00 A. M.

Autopsy on Dog of Experiment XII.

Dog died December 24th, and was put in cold storage until December 27th. Autopsy December 27, 1905.

There was but little infection in the superficial wound, and the tissues had begun to unite. In the

deeper layers of the wound, however, there was considerable pus, and on opening the left chest cavity there was found about 130 c.c. of thin reddish pus. At the most dependent part of the left chest cavity was found a large mass of lymph. The stump of the amputated lung was found lying in the center of an area that was distinctly infectious, and that was surrounded by a circumscribed area of lymph, but in no way was the stump walled off from the general cavity. The ligatures had held, although the stump had nearly sloughed off. The vessels, as traced up from the heart, were perfectly occluded at their amputated extremities. The bronchus, however, was severed and imbedded in a mass of exudate. It was very easy to force open the lumen. Within the right chest was found negative pressure, as evidenced by the inrush of air upon opening it. Within the right chest was found about 130 c.c. of thin reddish pus, similar to that in the left cavity, but without the exudation of lymph. The right lung was much compressed by the presence of the exudate, and was functionating only in a small portion. The pericardium contained a small amount of bloody serum. The heart was contracted in systole. There were a few clots in the ventricles, probably post-mortem. There were no protruding thrombii extending from the site of ligature into either the proximal part of the pulmonary artery or veins. The dog had apparently died of an infection from the bronchi starting at the site of the stump of the lung. As the right chest cavity had not been opened in any way, it is probable that the fluid found there was due to infection of that cavity through the lymphatics.

Microscopical Report on Right Lung. Slight peripheral or subpleural exudate.

EXPERIMENT XIII. December 28, 1905.

Fox-terrier. Ether.

Hoyt's machine and inflatable intubating canula used. Operation began at 11:00 A. M. and ended at 1:15 P. M. The right chest was not opened. The left chest was opened at about the fifth interspace, and the upper two lobes of the left lung were removed, tying them off with a number of silk ligatures. The stump was then drawn into a thin rubber tube, which

was tied around it tightly, and which led out to the surface of the chest. The chest was then closed and the anæsthesia stopped. The intubation-tube

Fig. XXI. Photograph of lungs of dog of experiment XIV (second series) injected with gelatine.

X shows the scar of lung operation. It will be noted that there were no adhesions. The glass tube passes through the œsophagus, V.

was removed, and, owing to carelessness, the dog died from asphyxia, from the dropping down of his tongue against the soft palate and against the pharynx, while our attention was diverted, and before artificial respiration could be again instituted.

On opening the chest immediately, the ligatures were found holding completely, and the chest cavity was entirely empty of any blood.

EXPERIMENT XIV. January 17, 1906.

Bull-terrier. Ether.

Hoyt's respiratory apparatus used, with special etherizing attachment and inflatable intubation canula. Operation began at 11:45 and ended at 12:50; average respiratory pressure being from 25 to 30 mm. of mercury; negative pressure being the same. The right side was not opened or punctured. The left side was opened between the ribs, at about the level of the fifth interspace. The lower lobe of the lung was drawn out, and a circumscribed area of it was surrounded by a silk ligature passed just under the serous covering of the lung, by means of a large blunt needle. (Fig. XVII.) This was then drawn tight and tied. (Fig. XVIII.) The portion of the lobe distal to the ligature was then removed by cutting, causing but very slight hemorrhage. No aspiration of air through the small bronchial tubes was observed. The exposed surface thus made was covered over by bringing the cut edges of the lung in apposition by a continuous suture. (Figs. XIX, XX.) Where the raw surface could not be covered this way, it was sutured up against the serous surface of the lung by a similar suture of silk. The remainder of the lobe was then dropped back in place, and the wound in the chest-wall closed layer by layer with interrupted silk sutures. The intubation-tube was then removed and the animal placed on its side to recover. The apparatus worked well throughout the operation.

January 18th. The dog has apparently suffered no shock. Has drunk a pan of milk, barked, pricked up his ears, and wagged his tail.

January 19th. The dog still continues to do well, and has been eating well. He whines quite a little, as if to attract attention. He is apparently very comfortable, and shows no ill effects whatever from operation, except a very slight cough.

March 14, 1906. Dog alive and well.

Autopsy on Dog of Experiment XIV. March 21, 1906.

The dog was killed with ether. Respiration ceased first; heart beat last. Dog well nourished, with considerable subcutaneous fat. The external scar is well healed. The lungs were injected with gelatine stained with carmine, under about two pounds air-pressure in situ. They were then removed and placed in ten per cent formalin solution. Lung repair was perfect; no adhesions. (See photograph, Fig. XXI.) Some of the silk sutures in the chest-wall were found in good condition. Around two was found a little walled-off suppuration.

Summary

FIRST SERIES

Experiments III and IV show the utility of artificial respiration in case of overdose of ether.

All the experiments exhibit a lack of material influence upon the blood-pressure by intubation, *per se*.

They also demonstrate that artificial respiration by means of positive pressure may be carried along in dogs, with but little change in the blood-pressure.

SECOND SERIES (RESECTION OF LUNG)

In the second series of fourteen animals, one dog died from direct leakage of air, alone. Five dogs died from sptice pleurisy. One dog died from carelessness, by asphyxia, after the operation was completed. In one dog the cause of death was uncertain. Six dogs lived two months or over, and recovered entirely; of these, four were killed for autopsy, one died $7\frac{1}{2}$ months after operation, of puerperal convulsions, while one is still living.

Comparing the results of J. B. Murphy with these, we see that in his series of ten dogs, three died of septic pleuritis, one died of accumulation of fluid, one died during anæsthesia, three died without certainty as to cause, and one recovered after drainage.

In my experiments, one dog recovered after drainage, that would undoubtedly have died without it. It is noticeable that some of the dogs recovered without drainage. A number died without drainage. It is possible that these would have recovered had the

facilities for proper drainage and maintenance of negative pressure within the pleura been perfected. It would appear, then, that the path to progress, after operations in the pleural cavity, lies in this direction; viz., drainage and negative pressure. Undoubtedly, Seidel's apparatus, or a modification of it, will materially help in transferring laboratory experiences to the field of operative intervention upon the human subject with increasing success.

The foregoing experiments justify the following statements. In dogs, the positive pressure method of artificial respiration is efficient; severe operations may be performed, with recovery; intubation is an easy and practical means by which to apply the positive pressure; the chief danger, after the operation is completed, lies in the accumulation, without proper drainage, of septic fluid within the chest.

The results of Sauerbruch's operations upon the human being, in thoracic conditions, are by no means discouraging. It seems reasonable that with either method here discussed the field of thoracic surgery will develop in the direction of active intervention, rather than continue along the present lines of expectant treatment.

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EXPERIMENTAL STUDIES UPON THE THORACIC ŒSOPHAGUS—A PRELIMINARY REPORT.

BY NATHAN W. GREEN, M.D.,
AND
J. W. DRAPER MAURY, M.D.,
OF NEW YORK.

THE purpose of the experiments outlined in this report is to determine what can be done transpleurally in the treatment of œsophageal stenosis while using the more simple positive pressure method of overcoming the embarrassment necessarily due to collapse of the lung during open chest work.

A few words may first be said concerning the apparatus used, the construction and the method of introduction of the intra-laryngeal tube. The air pump and valve is that designed by Mr. J. T. Hoyt of the physiological department and is of the type mentioned in a former paper.[1] The means of conveying the ether vapor is also the same as used in the experiments detailed in that paper. The canula, however, is much simpler and consists of a plain 8 mm. brass tube 12 in. long slightly curved and rounded at the laryngeal end and supplied with an obturator which tightly fits the rima glottidis. This consists merely of a few turns of surgeons' plaster so wound around the tube as to make a fusiform enlargement of about 12 mm. at its maximum diameter (see photo., Fig. 1). In the side of the tube near the aboral end is bored a small hole of about 2 mm. diameter. This serves as vent for the expired air. Around the tube is a small collar, a piece of tubing, which may be slipped over this aperture when it is necessary to inflate the lungs thoroughly before closing the chest wound. The aperture is sufficient for all expiratory purposes. No partial

[1] The Positive Pressure Method of Artificial Respiration with a Practical Device for its Application in Thoracic Surgery.—Surgery, Gynecology and Obstetrics, May, '06.

vacuum is used as it was demonstrated to be unnecessary. The intubation tube is held firmly in place by a light clamp made by incurving the blades of an Otis meatal dilator. This clamp is applied oral to the hyoid bone and is so adjusted as not even to bruise the skin under the floor of the mouth. Yet this simple appliance serves to hold the intubation tube firmly in place, and it was noticed repeatedly that neither the pressure from this clamp nor that exerted by the tube itself upon the vocal cords was sufficient to cause the least sign of paralysis. This was shown by the ability of the animal to bark immediately after recovery from anæsthesia.

The introduction of the tube is a very simple matter if attention be given to the following details. In the first place, the primary anæsthetization must be profound. The dog should then be placed squarely on its back with head extended. An attendant slips a towel over the canines of the upper and another over those of the lower jaw holding the mouth very widely open. The operator then holds the tongue in a third towel and draws it forward until the epiglottis is seen. If strong sunlight be thrown from above on the exterior of the neck, the proceeding is much facilitated, for it gives a very striking illumination through the tissues and enables the operator to place the tip of the intubation canula directly in the open rima.

Having completed the intubation and having secured the tube with the clamp, the dog is placed on its right side, a small cushion being tucked underneath the body opposite the site of the operation.

The 6th intercostal space is then located by counting from below up. The skin and superficial muscular incision is made over this space. The tissues are then drawn downward and the pleural cavity opened by sectioning the intercostal muscle midway between the ribs in the 7th space. This gives on closure of the wound an air tight flap—a condition very necessary in the dog, as leakage of air into one pleural space causes collapse of the opposite lung owing to the mobility of the soft parts forming the mediastinum.

Before the pleuritic layer is opened the condition of the lung should be studied by direct inspection and the amount of expansion regulated. This can easily be done as the pleura is quite transparent. Regulation of the expansion may be effected by gauging the volume of air delivered and by changing the size of the expiratory vent by the rubber collar already referred to.

Having opened the pleura, the ribs are then drawn apart and a self-retaining retractor inserted. This retractor, as shown in the photograph (Fig II), consists of a bent brass rod, it having been found more serviceable than the larger instrument designed for human use. The lung is then held out of the way by delicate retraction. This allows an immediate and unobstructed view of the œsophagus, for the ribs at the point of entry separate quite freely.[2] The vagi are usually found as two large trunks with a diagonally communicating branch. From this point on the manipulations must be of the most delicate nature possible. The vagi are carefully separated from the œsophagus by sharp dissection for a distance of 5 cm. Unavoidably much of the serous covering of the œsophagus is removed at this time, but it should be preserved so far as possible. At a point about 1 cm. oral to the point of investiture of the œsophagus by the diaphragm, a cuff of serosa is separated by circular incision around the œsophagus and this cuff is stripped down until the stomach appears in the wound.

The beginning decussation of the vagi on the stomach and the vessels, with the frequent exception of one branch which must be tied—are pushed back on the stomach. At this point the peritoneum appears on the left side and must be opened about half way around the œsophageal end of the stomach. After carefully protecting the cavities by pads a portion of the gastro-œsophageal juncture 2 cm. or more in length is removed. Clamps should not be employed as their use may be followed by a late perforation at the point maximum of pressure. Two retraction Lembert sutures are placed

[2] See abstract Sauerbruch's recent technic Kocher: Chirurg. Op. V aufl. p. 737 *et sec.*

in the oral part of the œsophagus which is then drawn up into the thoracic wound; the opening plugged with gauze and the stump covered with a pad. The wound caused by the resection of the gastric wall is then closed by a three-layer suture and the stomach is dropped back into the abdominal cavity. An adjacent portion of the cardiac end of the stomach is then grasped in the fingers and drawn up into the chest. Two retraction Lembert sutures are placed in the stomach and this organ incised between them. An end-to-side implantation of the œsophagus into the stomach is then made according to the usual method, three layers of silk sutures being used. The stomach is then dropped back into place again and the diaphragm sutured to the œsophagus oral to the point of union with the stomach, so making the gastro-œsophageal suture line intraperitoneal and within reach of the omentum (Fig. III). The chest cavity is then freed from any blood clots remaining, the positive pressure is slightly increased and the chest wound sutured in layers, leaving a small opening for the escape of air while the lungs are fully distended. This is finally closed and the operation is completed.

The conclusions from these incomplete studies are as follows:

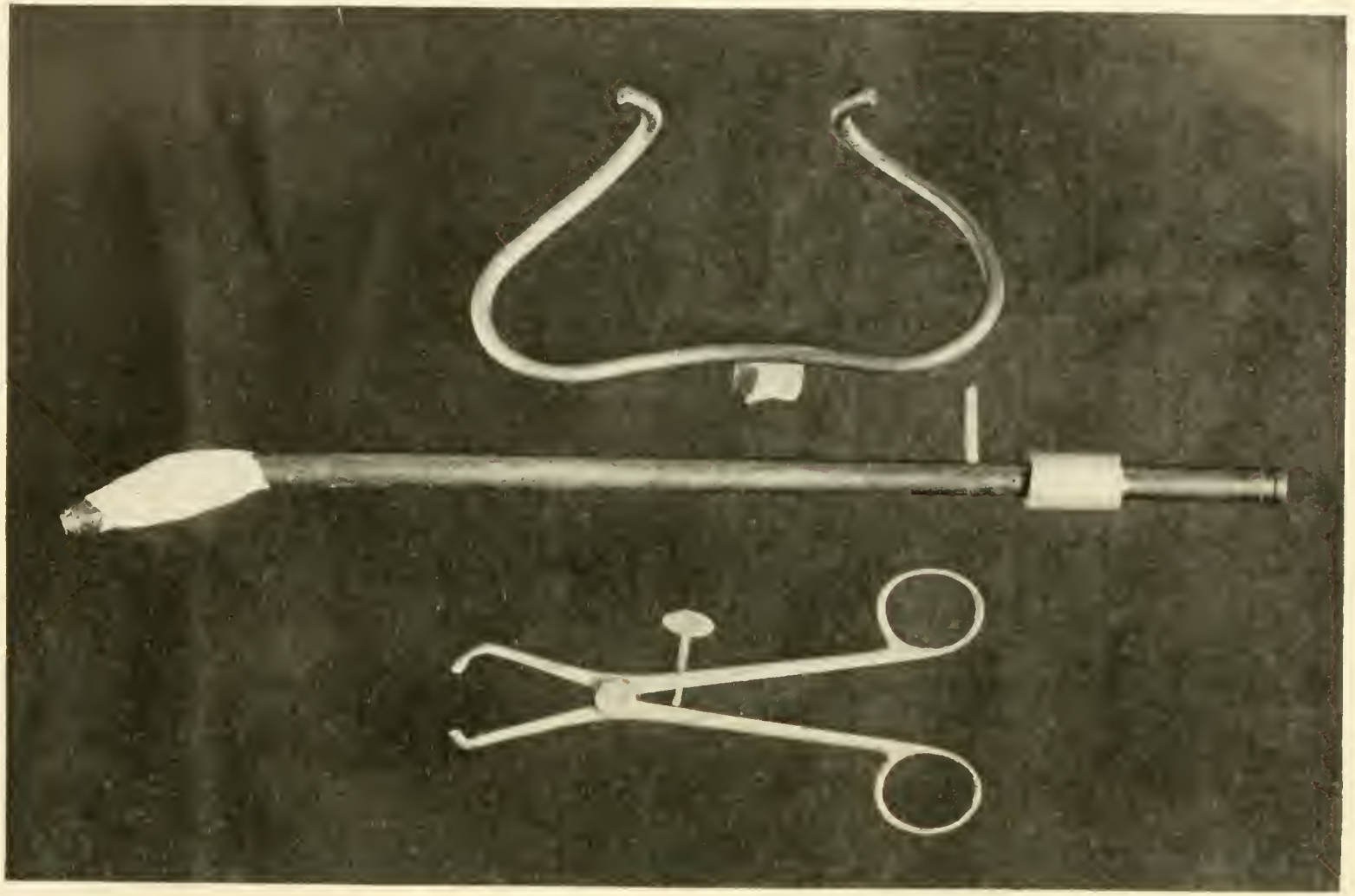
Intubation practised with the simple instruments described is thoroughly practical and for all surgical research work should supersede tracheotomy.

Positive pressure if supplied with a proper cut-off valve is a simple and efficient means for producing artificial respiration in surgical work. We have had no death directly attributable to it.

The flap formation in the chest wound is an important point in the technic.

The protection of the pleural cavity from infection must be rigidly enforced and when the point of resection is near the cardia this may be conveniently accomplished by the sequestration of the gastro-œsophogeal wound into the abdominal cavity. The omentum will then apply itself to the wound area as in any intestinal operation.

FIG. I.



Instruments to facilitate intra-thoracic work. A match has been inserted in the vent hole referred to in text.

Efforts to carry a portion of the omentum into the chest in order to profit by its protecting influence in case the wound area was too oral to allow of intra-peritoneal sequestration were sometimes successful, but it is difficult to maintain the omental blood supply by the method we employed.

In connection with these experiments we wish to report that we have tried gastro-œsophagostomy by means of the Murphy button—by means of end-to-end suture bringing the stomach up through a new opening in the diaphragm—by a lateral anastomosis, by one and also by two stages—and by the twine triangular stitch.[3] This last method we found very satisfactory in side-tracking the natural cardiac orifice. The photograph (Fig. IV) shows a view of a specimen so obtained. Our experience to date leads us to the belief that this or a two stage operation will prove to be the one of election, for the simple one stage intra-thoracic œsophageal section has a very high per cent. of septic mortality (in dogs).

We have also attempted Roux's method[4] of œsophago-jejunostomy. His technic was followed in all respects save that the gut segment was carried up through the chest instead of subcutaneously. Kocher,[5] after describing the method outlined by Roux, states that he essayed it on a man but was obliged to proceed to simple jejunostomy because of the failure of circulation in the isolated jejunal segment. Our results appear to justify the conclusion that in dogs at least the isolation of a portion of the jejunum by Roux's method is impracticable because of circulatory failure.

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[3] Twine in lieu of the elastic ligature for performing gastroenterostomy, Jour. A. M. A., Sept. 17, '04.

[4] Semaine Médicale, Jan., '07.

[5] Chirurgische Operations lehre, p. 907.

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RECTAL ANÆSTHESIA EXPERIMENTAL STUDIES TOGETHER WITH A REPORT OF ITS PRACTICAL EMPLOYMENT AT ROOSEVELT HOSPITAL.

BY NOEL BLEECKER LEGGETT, M.D.,
OF NEW YORK.

ETHERIZATION by rectum is by no means a new departure, for at different times in the past sixty years, methods have been sought whereby a patient might be anæsthetized by this method. Perigoff in his book on etherization published in 1847 mentions it. At the same time Roux in the Journal de l'Academie des Sciences, refers to the possible utility of rectal anæsthesia. Març Duprey employed ether pure or mixed with water as an injection for the purpose of producing anæsthesia. Malliere in 1884 used ether vapor obtained by boiling ether and letting the expanding gas force itself into the rectum. In the same year, Hunter reported six favorable cases. He praised the method, but did not mention any after effects. Weir (N. Y. Med. Rec., 1884, XXV, p. 507) gives seven cases reported by Dr. W. T. Bull, all of which had bloody stools following this method, besides two cases of his own, one of which ended disastrously.

Wanscher in the same year, 1884, records 22 cases of anæsthesia induced by injecting ether vapor into the rectum. All of his cases were favorable except one, in which he was unable to produce narcosis due to the presence of feces in the colon. But the next day after the colon was thoroughly cleaned out, the patient was readily anæsthetized. This shows the importance of having the lower bowel fully prepared before attempting narcosis (Congress Med. Sciences, 1884, p. 186, Sec. 1). Post reports three cases with no vomiting or diarrhœa (Boston Med. & Surg. Jour., 1884, CX, p. 442). Bux-

ton used this method and advocated its use for operations on the head, neck and for empyema.[1]

The method then lay idle from 1898 until two or three years ago when J. H. Cunningham of Boston again brought it before the public. He presented forty odd cases, all of which pointed to the practicability of rectal anæsthesia, if properly administered. Reading Dr. Cunningham's paper in the Boston Medical and Surgical Journal, it seemed, in view of his results with improved technic, that rectal anæsthesia had not had a full and fair trial in this city.

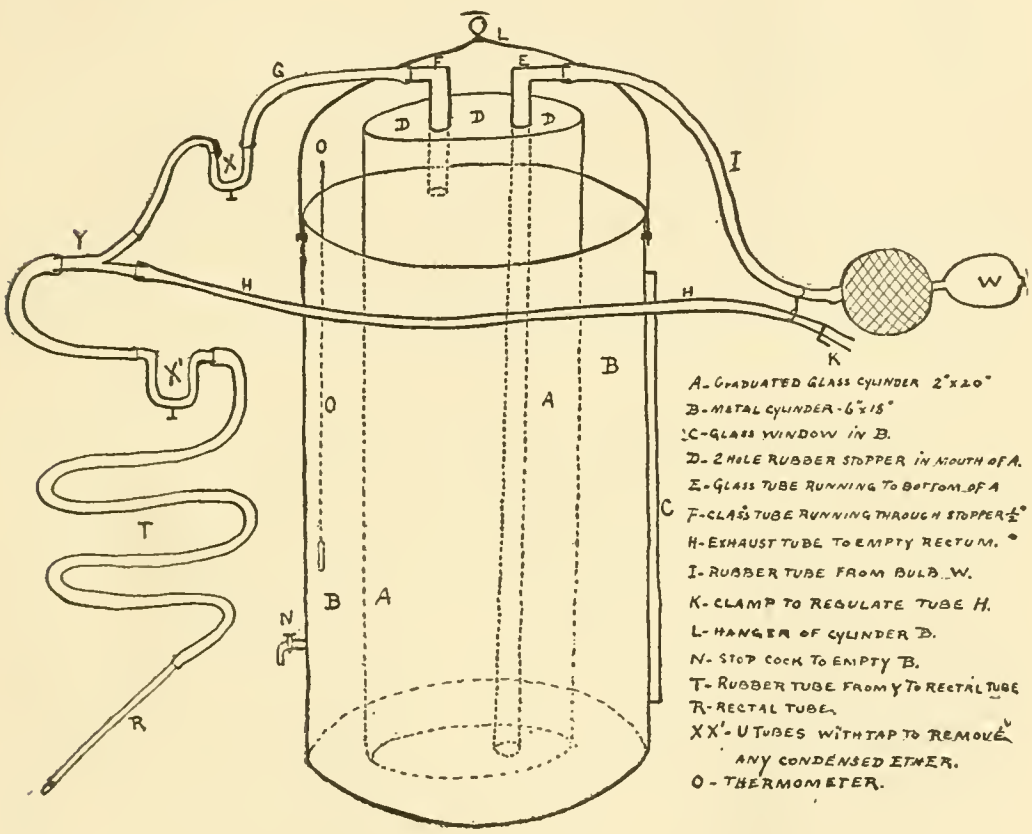
The method originally employed was that of boiling the ether in a vessel and allowing the expanding vapor to force itself into the rectum. In this way the vapor entered the rectum in such volume that there was a condensation in the tubes. Liquid ether was consequently forced into the gut, causing extreme irritation, ulceration and hemorrhagic proctitis.

Cunningham's method is somewhat similar, yet it varies in one vital point. The vapor of ether is forced into the rectum in such a way that there is no condensation, and absorption takes place with such rapidity that it is not possible for fluid ether to be forced into the gut. This is done by keeping the ether heated, yet constantly below 37° C. which is its boiling point, and forcing the fumes into the bowel by means of a rubber hand bulb. Herein lies the essential difference between the new technic and the old.

The apparatus is demonstrated in the accompanying cut. The effect upon the patient is as follows: He reclines in dorsal position with legs slightly flexed. The rectal tube is inserted 8 to 12 inches. Ether fumes are then slowly forced into the rectum. They cause a sensation of fullness so that the patient may have a desire to defecate. This is overcome by opening the exhaust tube at K and allowing the gases which are in the

[1] In 1898 S. J. Meltzer used ether by filling a bottle half full and placing it in a water-bath at a temperature above that of the rectum hot enough to boil the ether. He noted that ether is apparently more completely excreted when given by rectum than by the lungs.

rectum to escape. This should be repeated as often as may be necessary. It will immediately relieve any possible distress. The ether vapor is pumped in slowly, keeping the bowel comfortably full. The patient may have for a time slight discomfort, then becomes gradually drowsy and the odor of ether appears upon his breath. He falls asleep and in a comparatively short time has passed into full narcosis.


A- Graduated Glass Cylinder 2"x20"
B- Metal Cylinder-6"x18"
C- Glass Window in B.
D- 2 Hole Rubber Stopper in Mouth of A.
E- Glass Tube Running To Bottom of A
F- Glass Tube Running Through Stopper
H- Exhaust Tube To Empty Rectum.
I- Rubber Tube From Bulb W.
K- Clamp To Regulate Tube H.
L- Hanger of Cylinder B.
N- Stop Cock To Empty B.
T- Rubber Tube From Y To Rectal Tube
R- Rectal Tube.
XX'- U Tubes With Tap To Remove Any Condensed Ether.
O- Thermometer.

This method has its faults and its merits—its uses and its abuses. It will at once be conceded that if it can be made as free from danger as anæsthesia by mouth and free also from the danger of hemorrhagic proctitis, there are many operations about the head and neck in which its employment would be most useful. Studies directed toward determining what proportion of the ether administered is eliminated via the lungs are under consideration at the Laboratory. With the completion of these, it will be possible to state positively how

advantageous this method will be in cases of tuberculous pulmonary involvement.

Our post operative observations upon the patient may now be considered. The nausea, which in the inhalation method is still present despite many technical improvements is greatly decreased and in many cases absent after rectal anæsthesia.

So far I have given rectal anæsthesia in human beings in 13 cases only. We have, however, employed it upon dogs during a considerable period of experimentation. In these animals, it produces no proctitis, and if the fumes are allowed to pass the ileo-cecal valve, complete narcosis may be maintained for any length of time. Dogs have too short a colon to lend themselves favorably to this study. Through the kindness and interest of the attending staff of Roosevelt Hospital, I have had the privilege of using this method on the following cases:

Case No. 1.—It was one of cervical adenitis on Dr. Blake's service, operated upon by Dr. Martin; a boy, fourteen years old. Ether was started by the rectal method and in twelve minutes he became very heavy and drowsy, having had no discomfort whatsoever. After this, the patient muttered incoherently for a short time, then became quiet in 20 minutes after the ether was started and in 30 minutes there was absolute narcosis. The patient was under ether for 45 minutes during the operation, 85 minutes in all. The respirations were regular and full and there was none of the harsh rattling breathing due to bronchial secretions. The color was unusually good throughout the operation, and the blood was at all times well oxygenated. The patient made a rapid ether recovery, vomited once and had no rectal symptoms at all. Dr. Martin thought the blood did not coagulate as rapidly as usual.

Case No. II.—Dr. Blake's service. Operated on by Dr. Martin—tubercular rib. This patient had tubercular conditions in other parts of the body. Had taken ether several times previously. Ether was started by rectum and in ten minutes the patient was drowsy, although he complained a good deal at the length of time consumed. In twenty minutes, he was completely

anesthetized. Breathing was regular, pulse good and strong showing the stimulus of the ether. Patient was under ether anæsthesia for thirty minutes in all. He made a quick recovery and had no rectal symptoms. He complained simply of the length of time taken in producing sleep. Said the method was free from pain.

Case No. III.—Sacculated empyema. Operated upon by Dr. Blake. Anæsthesia was commenced both by inhalation and rectum, the patient being anesthetized in five minutes, then the ether continued by rectum during the operation, which lasted twenty minutes. The breathing was full and regular, color perfect and pulse all that could be desired. Rapid ether recovery with no rectal symptoms of any kind.

Case No. IV.—Sarcoma of frontal sinus. Operated upon by Dr. Blake. Patient had had ether twice previous to this. Ether was started by mouth and rectum and in ten minutes the patient was completely anæsthetized, when the inhalation was discontinued, but ether continued by rectum. The patient began to come out before reaching the table, so inhalations were again given till complete narcosis was again obtained, when it was discontinued. The patient again came out, and anesthesia by mouth was continued for the rest of the operation. This case was one in which the rectal method was not effectual. It demonstrated, however, with the preceding, that the ether vapor has no ill effect upon the mucous membrane of the colon, for the patient came through with no colic or other untoward symptoms.

Case No. V.—Dr. Blake's service. Dr. Martin operating. Cervical adenitis. Rectal ether started and given for ten minutes when patient became drowsy. The operator being ready, ether was given by mouth till the patient was anæsthetized, then anesthesia continued by rectum for one hour. The patient was in perfect condition throughout the whole of this time, made a good quick ether recovery with little vomiting and no rectal symptoms.

Case No. VI.—Epulis. Dr. Martin operating on Dr. Blake's service. Ether began 12:15 by mouth and rectum. Patient under in five minutes when ether was continued by rectum for twenty-five minutes. Recovery with very little vomiting and no colon nor rectal symptoms.

Case No. VII.—Hydrocephalus in a child three years old.

Operated upon by Dr. Brewer. Child was anæsthetized by mouth and rectum and then anæsthesia continued by rectum. Patient lost sensation in three minutes. The ether was continued for fifty minutes in all. At one time stimulants had to be given due to the shock of the operation as much as to any effect of the ether, if not wholly so. The child's ether recovery was rapid with some vomiting, but absolutely without any rectal irritation.

Case No. VIII.—Axillary Carcinoma. Operated upon by Dr. Blake. Ether was started by mouth and rectum. The woman was fully anæsthetized in a few minutes. Patient defecated while going under. As soon as inhalation was stopped, patient began to come out of ether, and it had to be continued by mouth. The patient defecated several times, at last clogging rectal tube, so ether had to be stopped by rectum. Colon had not been adequately cleaned.

This case shows that it is most necessary to have the bowel fully cleaned before the patient can absorb the ether rapidly enough to keep up complete narcosis.

Case No. IX.—Dr. Martin. Cervical Adenitis. Child—girl 5 years. Ether started by mouth and rectum. Patient anæsthetized in 3 minutes. Patient was under ether 30 minutes. The rectum being partially filled, it was difficult to regulate the anæsthesia. Patient defecated twice. Rapid recovery. Very little vomiting.

Case No. X.—Dr. Blake. Cervical Adenitis—boy 16 years. Ether started by mouth and rectum. Patient anæsthetized fully in 5 minutes. Then ether continued per rectum. Patient under 30 minutes. No bronchial secretions. Patient at first was hard to control but in a short time was fully in a lax and narcosed condition. Patient made rapid ether recovery with no vomiting and no rectal distress.

Case No. XI.—Dr. Brewer. Tubercular Laryngitis. Adult. 3.15 Morphine Sulphate, gr. ¼ given by hypo.

3.30 Ether by mouth and rectum. Ether continued by rectum 65 minutes; respiration, full, strong and regular; the pulse good.

Patient recovered from the ether rapidly with no rectal distress, and very little nausea or vomiting.

Case No. XII.—Dr. Brewer. Carcinoma of Face. Ether

commenced by mouth and rectum and continued by rectum alone for 20 minutes. Rapid and easily recovery.

Case No. XIII.—Dr. Flint. Epithelioma of Lower Maxilla. Resection of Maxilla. Ether started 2.15 P.M. Patient on the operating table 2.35, when ether was continued by rectum until 3.20. Color of patient good; pulse slightly rapid; no condition of shock. Rapid ether recovery with very greatly decreased nausea and vomiting.

These cases, though few show in a small way the possibilities which this method of etherization offers, both to patient and to operator.

Rectal anæsthesia may thus be summed up from two standpoints, viz., from that of the patient and from that of the operator.

The lessening of nausea, the lessening of irritation to the lungs and the lessening of the bronchial secretions which were nearly entirely absent in most of the cases are certainly all in themselves favorable. Furthermore, a fully and continuously clear field of action in all operations about the head and neck saving time and loss of blood and above all lessening the chance of infection from an ether cone, are all points in favor of the method which must appeal to every operating surgeon.

The chief points about the apparatus which we believe to be new and useful are, first the introduction of the Y and exhaust tube to empty rectum and second the glass U tubes which enable one to be certain that no liquid ether is passing into the rectum. It is a convenience and a safeguard for the anæsthetist to be able to empty the rectum of gas or of ether vapor at a moment's notice.

Since sending the above to the publisher I have had the good fortune to collect through the kindness of Dr. W. S. Sutton, of the Roosevelt staff, eighteen additional records of the use of rectal anæsthesia at the hospital. This makes a total of thirty-one (31) cases.

Two of these recent records deserve particular attention.

In the first case the patient was markedly alcoholic and therefore a large ether consumer. After ether recovery he had one small rectal hemorrhage. The cause of this is unknown. All succeeding movements were blood-free.

In the second case, Dr. Chas. H. Reck operated for the removal of an enlarged thyroid. He was struck by the advantages offered by rectal anæsthesia in this class of cases and believed that under favorable conditions it might in time supplant the slower method of cocaine infiltration.

A large number of suitable cases are now being anæsthetized by the rectal method at Roosevelt Hospital, and when Sutton's conclusions are published we shall know quite positively the advantages accruing from Cunningham's new technic.

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Columbia University. College
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Studies from the laboratories
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GERSTS